

ON READING CHINESE CHARACTERS —
~~-- An experimental and neuropsychological study~~
and experimental study.

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ABSTRACT

The research reported here attempts to identify those reading processes common to both alphabetic readers and readers of Chinese logographic characters, and those processes unique to Chinese reading. Three types of evidence are presented: (1) experimental studies of normal Chinese readers; (2) clinical and experimental investigations of Chinese patients with acquired dyslexic symptoms; (3) a survey of developmental dyslexia in China. Like alphabetic readers, Chinese readers show independent procedures for mapping from orthography to meaning and from orthography to sound. Also like alphabetic readers, the mapping to sound can be accomplished by both a lexical and a sublexical procedure. The special characteristics of Chinese script are analysed and their significance in reading processes are revealed.

The research is presented in six chapters.

Chapter 1 is the background of this study which contains a general review of reading studies of Chinese and other scripts, the main theoretical issues and the objectives of this study.

Chapter 2 presents a new analysis of statistical properties of Chinese characters including the consistency of phonetic radicals.

Chapter 3 presents experiments on reading Chinese characters by normal Chinese readers. In these studies, phonological recoding is demonstrated; the lateralization of reading Chinese characters is investigated; and finally, the errors of normal subjects' reading is examined.

Chapter 4 contains a clinical study on Chinese acquired dyslexic patients. In this study, several Chinese acquired dyslexic symptoms are reported for the first time. Analogues of surface and deep dyslexia in Chinese patients are described for the first time. This supports the idea of independent lexical and sublexical procedures for mapping from orthography to sound. However, Chinese surface and deep dyslexia show features distinct from their alphabetic counterparts. In addition, it is also revealed that there are some special dyslexic symptoms which are predictable from the characteristics of Chinese script which I term associative dyslexia and compound dyslexia.

Chapter 5 contains a survey on developmental dyslexia among 8106 Chinese pupils in which the ratio of developmental dyslexia is found to be lower (1.92%) than in alphabetic children.

Chapter 6 presents the theoretical implications of the studies taken together for Chinese reading and for reading generally.

CONTENTS

<u>Chapter</u>	<u>Page</u>
1. Introduction	13
1.1. Some key issues in cognitive reading studies	15
1.2. Cognitive reading models	17
1.2.1. Single-route reading model	17
1.2.2. Multi-route reading models	18
1.2.3. General remarks on the models of reading	23
1.3. Three approaches to reading studies	23
1.4. Reading studies on alphabetic languages	24
1.4.1. Experimental studies on reading alphabetic words	24
1.4.2. Acquired dyslexia studies on reading alphabetic words	30
1.4.3. Studies of developmental dyslexia of alphabetic languages	52
1.4.4. Summary of studies on reading alphabetic languages	60
1.5. Script effects on reading	61
1.5.1. Experimental reading studies	61
1.5.2. Acquired dyslexia studies	63
1.5.3. Developmental dyslexia studies	66
1.5.4. Summary of script effects on reading	67
1.6. Studies on reading Chinese characters	68
1.6.1. Experimental studies on reading Chinese characters	68

1.6.2. Chinese acquired dyslexia studies	75
1.6.3. Chinese developmental dyslexia studies	77
1.6.4. Summary of studies of reading Chinese characters	78
1.7. Questions and objectives of this study	80
2. Analysis of Chinese characters	87
2.1. The Chinese language and Chinese characters	87
2.1.1. Languages used in China	87
2.1.2. Hanyu and its sound system	87
2.1.3. Chinese characters are the unified written form of Hanyu	89
2.1.4. The origin and development of Chinese characters	90
2.1.5. The current reform of Hanyu and the simplification of Chinese characters	92
2.1.6. The influence of Chinese characters over other languages in East Asia	93
2.1.7. The problem of Chinese illiteracy and learning to read Chinese characters	95
2.2. The structure of Chinese characters	98
2.2.1. Four types of Chinese characters	98
2.2.2. Two sorts of constructions	101
2.3. The phonology of Chinese characters	104
2.3.1. Sound representation and its reliability and accuracy	104
2.3.2. Monosyllabic system and the reliability	

in determining meaning by sound	115
2.4. Conclusion	121
3. Experimental studies on reading Chinese characters	
3.1. Introduction	125
3.2. Automatic/obligatory phonological processing in reading Chinese characters (experiment one)	125
3.3. Lateralisation of reading Chinese characters	134
3.3.1. Lateralisation of recognition (experiment two)	137
3.3.2. Lateralisation of articulatory processes (experiment three)	145
3.3.3. Lateralisation of phonological processing (experiment four)	152
3.3.4. Lateralisation of semantic processing (experiment five)	159
3.3.5. Summary of lateralization experiments	165
3.4. Normal errors in speeded reading (experiment six)	167
4. Chinese acquired dyslexia.....	180
4.1. Introduction	180
4.2. The aims and methods of the study	185
4.3. Case reports	194
4.4. Results of reading tests	200
4.4.1. The routes in reading Chinese characters	202
4.4.2. Analysis of the deep dyslexic symptom	

-- semantic errors.....	215
4.4.3. A vocabulary analysis of a deep dyslexic patient	219
4.4.4. Comparison between "surface" and "deep" dyslexic patients	223
4.4.5. Script specific features in reading processes: some characteristics of reading Chinese characters	228
4.5. Discussion	234
4.6. Conclusion	243
5. Chinese developmental dyslexia.....	245
5.1. Introduction	245
5.2. Design	246
5.3. Method	250
5.4. Results	250
5.4.1. Ratio of developmental reading disorder pupils	251
5.4.2. Ratio of reading difficulty with Pinyin.....	252
5.4.3. Occurrence of symptoms	253
5.4.4. Distribution of symptoms	254
5.4.5. Correlation and factor analysis	259
5.4.6. Handedness	263
5.4.7. Sex	265
5.4.8. Grade	267
5.4.9. Handedness, sex and grade interrelation in reading symptoms	269

5.5. Discussion	271
5.6. Conclusion	280
6. A theoretical consideration on reading	
Chinese characters.....	281
6.1. Background	281
6.2. A possible model for reading	
Chinese characters.....	283
6.3. Summary of the results of my studies	287
6.3.1. Phonological recoding in reading Chinese	
characters.....	287
6.3.2. Are there different routes to a	
character's sound?.....	288
6.3.3. Can the route to meaning be independent	
of the route(s) to sound?.....	290
6.3.4. Access to characters' meaning.....	291
6.3.5. On the configuration aspect on reading	
Chinese characters and the features	
associated with reading associative	
characters and compound words.....	293
6.3.6. On lateralization.....	296
6.3.7. On the developmental dyslexia issue.....	297
6.4. Conclusion.....	299
6.5. Directions for future research.....	300
6.5.1. In the experimental field.....	300
6.5.2. In the clinical field.....	302
6.5.3. In the developmental field.....	303

References.....	304
Appendix A. Tables of experimental studies.....	323
Appendix B. Tables of developmental dyslexia studies.....	339
Appendix C. CT scan of 11 Chinese dyslexic patients.....	341

LIST OF TABLES

	<u>Page</u>
Chapter 3 tables	
3.1. Three-way anova with 1 rptd measure (RT correct)...	131
3.2. Mean R.T. (correct) etc. Differences among different tasks.....	132
3.3. T test of RT for paired left versus right visual fields in recognizing real, or pseudo, or non characters.....	141
3.4. T test of rate of wrong reactions for paired left versus right visual fields in recognizing real, or pseudo, or non characters.....	142
3.5. Two way ANOVA with one repeated measures for RT in naming test.....	148
3.6. T test for mean RT between left visual field and right visual field.....	149
3.7. T test for accuracy of naming between left visual field and right visual field.....	150
3.8. Three way ANOVA for RT in judging homophone pairs.....	156
3.9. T test for RT between the left visual	

field and right visual field.....	157
3.10. T test for accuracy of performance in judging homophone pairs between the left visual field and the right visual field.....	157
3.11. Three ways anova with one repeat measure for RT in antonym judgment experiment.....	163
3.12. T test for judging antonym pairs between the left visual field and right visual field.....	164
3.13. The numbers of errors of different types made by each subject.....	171

Chapter 4 tables

4.1. Patient summary	198
4.2. Summary of reading tests	200
4.3. Result of naming and matching tests (QXS)	202
4.4. Result of naming and matching tests (LYM)	210
4.5. Result of naming and matching tests (LWY)	211
4.6. Result of naming and matching tests (ZZG)	211
4.7. Single word reading of deep and surface dyslexic patients	224
4.8. Deep and Surface dyslexic patients' semantic error and regularization ratio	226

Chapter 5 tables

5.1. General occurrence of symptoms	253
5.2. The distribution of symptoms in pupils	

being surveyed	255
5.3. The distribution of symptoms in pupils without reported reading disorder.....	256
5.4. The distribution of symptoms in reported reading disorder pupils	257
5.5. Correlations between reading disorder and other symptoms	260
5.6. Factor analysis on reported reading disorder pupils	261
5.7. Factor analysis on symptom holders	262
5.8. The number of reported reading disorder pupils and the occurrence of symptoms in left-handed pupils comparing with that in non left-handed pupils.....	264
5.9. The number of reported reading disorder pupils and the occurrence of symptoms in boys and girls...	266
5.10. The ratio of reading disability and occurrence of symptoms in 2 to 6 grades.....	268
5.11. The number of left-handed pupils and number of reported reading disorder pupils in both sexes and in each of the 2 to 6 grades.....	270

LIST OF FIGURES

	<u>Page</u>
Chapter 2 figures	
2.1. Distribution of RP's	114
2.2. Sound representation	115
Chapter 4 figures	
4.1. Surface dyslexia symptoms	207
4.2. Single word reading	225
Chapter 5 figures	
5.1. General occurrence of symptoms	254
5.2. Distribution of symptoms (1)	255
5.3. Distribution of symptoms (2)	257
5.4. Distribution of symptoms (3)	258
5.5. Distribution of symptoms (4)	259
5.6. Handedness difference	265
5.7. Sex difference	267
5.8. Grade difference	269
5.9. Sex, grade and reading disorder	271
Chapter 6 figure	
6.1. A model of reading Chinese characters	284

CHAPTER 1

INTRODUCTION

An important issue in the field of psychology of reading is whether reading has some universal features which are common for different kinds of writing systems, and whether reading has some specific features which are script dependent. My research aims to provide information on these aspects of reading by carrying out experimental and neuropsychological studies on reading Chinese characters. As we know there have been many studies of reading alphabetic scripts, but few studies of non-alphabetic scripts, especially Chinese characters, although it is obvious that Chinese characters are an extreme case of non-alphabetic written scripts.

Chinese characters are one of the oldest writing forms in the world, and its present users cover almost a quarter of the world's population. As a logographic system, Chinese characters are different from the alphabetic system in two main ways. (1) The role of phonology. Alphabetic words are constructed from letters which represent phonemes according to spelling-to-sound rules. In contrast, Chinese characters are constructed by strokes that do not represent phonemes. There is no spelling-to-sound system. However many radicals (which are made by strokes and used mostly as sub-characters) are used to represent the whole pronunciation of a character, though this representation is quite inconsistent. (2) The visual form. Alphabetic words are constructed by arranging letters in linear order. Chinese characters are constructed in two dimensions as a square structure with a variable number of strokes

(in modern Chinese, the average number of strokes in a character is about 10). Moreover, there are different types of character, i.e. pictographic characters, indicative characters, associative characters and pictophonetic characters. These make the visual form of the script even more complex. Furthermore, although Chinese characters are weak in representing their sound, they are strong in representing their meaning through their forms, and different types of characters have different ways of representing their meaning.

Apart from the above two main aspects, there are some other features which also make Chinese characters special. These features are: (a) Chinese characters represent single syllables, and thus it is unified both in configuration and in phonology. (b) The linguistic unit which a Chinese character stands for is the morpheme. Because of this, a single character is not always a word. This is different from alphabetic languages where words are distinguished clearly in the written form. In Chinese, words are not very clearly distinguished.

The obvious differences between Chinese characters and alphabetic words is reflected in the learning processes. Learning to read Chinese characters is not an easy task. Pupils have to first of all learn the strokes, then radicals and then characters. At the same time as they are learning the structure of the characters they are also learning a phonological system, Pinyin, to help them to correctly pronounce characters. However, Pinyin does not appear in normal Chinese texts. Learning to read Chinese

character demands more time and effort than learning to read alphabetic words.

As for establishing the universal and language specific features of reading, we need to know whether or not the principles obtained from the studies on alphabetic words which have a spelling-to-sound system are applicable to reading Chinese characters which do not have such system. Are the reading processes are basically the same or similar or very different? Does phonology play a role in reading Chinese characters? Are the sound radicals in Chinese characters important in this respect? Are there any special features in reading Chinese characters, especially due to their complex structures?

To set a background for this study, we need to review the key issues, cognitive models, and the main approaches used in cognitive studies. Secondly, we need to review studies on reading alphabetic words and the main approaches used. Thirdly, we need to examine script differences already established, especially through considering reading studies of the Japanese. Fourthly, we examine the studies on reading Chinese. Finally, questions for further study on reading Chinese characters is presented and the aim of this study is further explained.

1.1. SOME KEY ISSUES IN COGNITIVE READING STUDIES

There are three main questions concerning the reading process: 1. Is the transcoding from word to pronunciation accomplished by more than one process? 2. Is the transcoding from word to meaning accomplished by more than one process? 3. Are the

types of transcoding independent? Affiliated with these questions, there is another important enquiry: does phonological recoding exist in reading and what is the role it plays. Around these principal questions, many cognitive reading models are proposed to explain the reading processes. These cognitive reading models are closely linked to cognitive neuropsychological research methods. By using carefully selected psycholinguistic materials it is possible to reveal selective deficits for specific types of materials, and hence several different types of cognitive reading dysfunction. This has led to the postulation of different types of acquired dyslexia: deep dyslexia, surface dyslexia, phonological dyslexia. Cognitive neuropsychological models have been put forward to explain the cognitive causes for these different types of acquired dyslexia. At the same time, these also aim to build up a model for normal reading processes (Coltheart, 1981; Morton and Patterson, 1980; Newcombe and Marshall, 1980; Shallice, 1981).

Apart from the above main questions about reading, there is another important aspect in reading which we should not ignore: cerebral lateralization. In fact, the issue of lateralization of reading is closely related to the the issue of the routes used in reading. This relationship becomes apparent in the controversial theory of the cause of deep dyslexia, which claims that it is the result of reading with the right hemisphere. With regard to the visual features of Chinese characters, the cerebral lateralization of reading such a script turns out to be an even more important issue which we have to pay much attention to.

Three kinds of studies suggest that reading is left lateralised. One is the research on split brain patients in which the left hemisphere is revealed to have a dominant capacity over the right hemisphere in reading (Sperry, et al. 1969). The second source of evidence is from the research on patients with unilateral cerebral injuries. It has been found in these field that disorders affecting reading are, like other language disorders, typically linked to left cerebral injury (Young, 1987). The third sort of support is from the studies on normal subjects using tachistoscopical presentation technique. In these studies, a dominant finding is that there is usually a superior performance for the right visual field -i.e. LH- when words are briefly presented for reading (Beaumont, 1982).

1.2. COGNITIVE READING MODELS

Cognitive models can be divided into two categories: (1) The single route model which claims that reading is achieved by just one set of processes. (2) The multiple route model which claims that reading procedure (either in the case of transcoding from print to the meaning or in the case of transcoding from print to the pronunciation) is achieved by more than one route, and that these routes are independent.

1.2.1. SINGLE-ROUTE READING MODEL

There are mainly two kinds of models included in this category. I would like to call them a classical single route model and a modern one.

PURE PHONETIC READING THEORY

This is what I would call classical single route reading model. This model claims that reading words can only be achieved by phonological recoding (Rubenstein, et al. 1971; Gough, 1972). Obviously, this pure phonetic reading theory adopts a rigid attitude to the reading processes.

KAY AND MARCEL'S ANALOGY MODEL

Different from the classical single route model, there is also a kind of single route reading theory which adopts a more flexible attitude to reading processes in terms of analogy, and I would like to call it the modern one. Like Rubenstein, Kay and Marcel (1981) also suggested that there is only one route for converting print to sound. But the basis for this single route is the analogy process. According to their model, a visual input lexicon is specified for all known words and morphemes, they are coded in terms of a left-to-right description of letters in ordinal positions. Each address in the visual input lexicon has a connection to a semantic description and an entry or entries in the output lexicon. In normal reading aloud processes, the phonology of both words and non-words is retrieved by analogy with all known words having matching segments. For reading disorders, like surface dyslexia, they argued that it could be explained in terms of the use of inappropriate analogies.

1.2.2. MULTI-ROUTE READING MODELS

Many psychologists favour this kind of model (Morton, 1979; Barron et al. 1977; Allport, 1977, 1979; Coltheart, 1978, 1980; Forster and Chambers, 1973; Frederiksen and Kroll, 1976; Marcel and

Patterson, 1978; Newcombe and Marshall, 1980; Morton and Patterson, 1980). Although there are many versions of this multi-route model, the principles, as we will see, are similar.

LOGOGEN MODEL

This is a well-known model about mental lexicon proposed by Morton (1979). Originally, this model was concerned with the nature of the activation and representation of words. It was a later development that made the model applicable for the reading process. In this model, Morton postulated the existence of "logogens", or abstract units of word recognition. Such a unit corresponds to an individual word (or morpheme) and underlies the perception or production of this word. In reading, two sets of logogens are proposed. One is the visual input logogen, the other is the output logogen. This distinction between input logogen and output logogen came with the development of neuropsychological models for reading letter strings aloud. However, the possibility of a single lexicon has also been discussed (Allport & Funnell, 1982). The visual input logogen recognizes the visual representations of words. The units of the logogen system have thresholds of activation. When a logogen reaches threshold the word is recognized and transmitted to the cognitive system to be assigned a meaning. The output logogen, following the cognitive system, which stores representations of the oral pronunciation of words. Responses from this system are held in a response buffer prior to output. This process forms a reading route through the semantic system. In addition to this semantic route, there is a direct reading route which goes directly from input logogens to output logogens without proceeding to semantics. On these two routes, phonological recoding is not essential since without it the meaning and the pronunciation of a written word can be achieved. Apart from these two routes, there is a distinct phonological reading route characterized by phonological recoding. Thus non-words or unfamiliar words can be read. The logogen model has undergone continuous revision. To explain the sophisticated

reading symptoms of deep dyslexia, Morton and Patterson (1980) used the recent logogen model with additional detailed explanation, while the main features are retained.

MARSHALL AND NEWCOMBE MODEL

In their very important paper on acquired dyslexia (1973) which created a new cognitive trend in this field, Marshall and Newcombe proposed a two route model for explaining the various paralexia symptoms they have observed. In their original model, they defined several cognitive components: a visual register which connected immediately with the stimulus; visual addresses which connect visual register with semantic addresses and phonological addresses; articulatory addresses which determine the final response; the articulatory addresses are connected with phonological addresses and semantic addresses through a threshold mechanism which controls the connection. In reading individual words, visual addresses must be associated with stimulus entries in a primary visual register; then either goes to phonological addresses or semantic addresses. Before a pronunciation is finally achieved the value from either phonological addresses or semantic addresses must exceed a certain threshold. When this is done, an articulatory address is associated which then determines the final response. To accommodate more complex symptoms found in acquired dyslexia, Newcombe and Marshall (1980) have refined the original model in more detail. A significant feature of the new version of their model is that they conjecture that the semantic system is intrinsically unstable and that peripheral devices (such as

grapheme-phoneme conversion system) act as a stabilizing mechanism to prevent errors. Thus the semantic errors found in deep dyslexia can be successfully explained in comparison with normal adult reading.

COLT HEART MODEL

Coltheart model (1980) postulates the existence of an internal lexicon which embodies all the information a person has concerning the words in his vocabulary. In reading a word, three pathways can be used. Pathway A is the route by which a printed letter string connects with the internal lexicon via visual codes and then to pronunciation. Pathway B is the route by which printed letter string connects with internal lexicon via phonological codes and then to pronunciation. Pathway C is the route by which printed letter string connects with pronunciation via phonological codes. Pathway C is also called non-lexical route. This route, depends upon the use of a grapheme-phoneme conversion system (GPCs). Coltheart reasons that since we can pronounce exception words correctly, pathway A must exist; since we are able to answer correctly questions requiring semantic decision about pseudo-homophones (for example, does PHOCKS sound like a kind of animal?), pathway B must exist; and finally, since we can pronounce non-words, pathway C must exist.

HORSE-RACE MODEL

Forster and Chambers (1973) proposed the horse-race model of conversion of print to sound in which two pathways are available for naming words, one is the lexical search route, the other is the

GPC translation route, and they thought that words can be successfully processed by either route. In the reading process, two pathways are started simultaneously and a race therefore is in progress. A final solution will be made by such competition with a response achieved through the faster route (Forster and Chambers, 1973).

SEIDENBERG TIME COURSE MODEL

Similar to the horse-race model, Seidenberg and his colleagues have developed the time course model to explain the reading processes (Seidenberg, et al., 1984; Seidenberg, 1985). It assumes that access to phonology is an automatic consequence of recognition, and emphasizes an interactive process with differences in the time course of orthographic and phonological activation. Whether recognition needs phonological information depends on the time course of the decoding process. Recognition begins with the extraction of visual information from the input, resulting in interaction amongst members of an orthographic neighborhood. When an orthographic unit is recognized, it activates its phonological representations. When sufficient orthographic information is extracted from the input, recognition can be achieved prior to access of phonology. High frequency words are easier to recognise because of more neighborhood effects in the mental lexicon in comparison with low frequency words. The slower recognition of lower frequency words allows more time for phonological information to accumulate and activate their phonological representations. As a result, there will be phonological mediation only for the more slowly recognized, lower frequency words. The time course model has developed from consideration of some experimental findings

which do not fit other multi-route models, such as irregular spelling-sound correspondences only influence the recognition of lower frequency words. Exception words yield longer naming latencies than regular words only when they are relatively low in frequency (Glushko, 1979; Seidenberg, et al., 1984).

1.2.3. GENERAL REMARKS ON THE MODELS OF READING

At the present time, multi-route models are more popular than single-route models. Multi-route models are more convincing because they can explain most symptoms found in acquired dyslexia which are regarded as the major evidence for reading routes. Nowadays, it is hard to find psychologists who still believe old single route models (purely phonetic one). But the modern single-route models (the analogy model) still challenges the multi-route models.

So far, we have generally discussed main theoretical issues of reading and some main cognitive reading models. We now come to the question of what the main approaches used for exploring these issues are.

1.3. THREE APPROACHES TO READING STUDIES

There are three closely related approaches used by psychologists for reading research. The first is the experimental study of normal adults' reading process. The second is clinical experimental study of acquired dyslexic patients. The third is the study of reading developmental children and its disorders.

Experiments on groups of normal subjects is the traditional method for analysing psychological processes. As for the above reading issues, this approach can provide evidence of normal adult

reading processes especially on the aspects such as phonological recoding, word recognition, and the cerebral lateralization of reading.

Acquired dyslexia study is a major approach for exploring the cognitive reading routes. It is this method that provides vital evidence for identifying different routes in reading.

Developmental dyslexia study is an important aspect in reading research. Although there is a theoretical question which is whether the acquisition of literacy, and developmental dyslexia, can be interpreted over the same functional structure that is implicated in adult reading performance, the studies of developmental dyslexia do provide much important information which help understanding the normal adults' reading processes. Developmental dyslexia study can explore the reading processes longitudinally and thus provide us the opportunities to see the reading processes from developmental angles.

Apparently, the above three research approaches in reading study tackle the same reading processes from different, but closely related angles. It is also very clear the important thing is to put the three approaches together for a sound understanding of our reading process. Now let us see what we have obtained from the three approaches.

1.4. READING STUDIES ON ALPHABETIC LANGUAGES

1.4.1. EXPERIMENTAL STUDIES ON READING ALPHABETIC WORDS

In this field, many experiments have been carried out on two main issues: one is phonological recoding in reading, the other is

the lateralization of *the hemispheres* in reading. These two issues are important for establishing the model of reading processes. The importance of phonological recoding is obvious as it is the basic function of phonological route in reading. As for the lateralization of hemisphere in reading, we have noted that it has been a focus of reading studies as far as the neuropsychological mechanism is concerned. With regards to the routes of reading processes, I would say that it actually closely relates to the phonological process. Because of these, I will review the studies on these two issues.

PHONOLOGICAL RECODING

Does reading need phonological recoding? Psychologists have very different opinions about this question. Some regard reading as mainly a process of translating written symbols to sound. For example, Venezky (1967) regards the basic thing in reading as transferring written script into sound. Some psychologists, such as Smith (1978), think that what really happens in reading is not the translation from visual symbols to sound, but the translation from visual symbols to meaning, in other words, phonological recoding is not necessary in reading, at least reading for meaning.

Of these two very different opinions, which is right and which is wrong? For years psychologists have made lots of experiments in studying this problem, and much research is in favour of the existence of phonological recoding in reading process.

Conrad (1964) made an influential experiment which revealed

the existence of phonological recoding in a memory task when subjects were processing verbal materials even when these materials were visually presented. Since then, a lot of research has also demonstrated that phonological recoding occurs in reading, such as: Krueger (1970) found that acoustic confusion affected the speed of searching for a particular letter. Corcoran and Veening (1968) revealed that the omission of pronounced letters was easier to detect than unpronounced letters in a reading test. Rubenstein, Lewis, and Rubenstein (1971) provided evidence demonstrating that pronounceable non-words which sound like words are *more difficult* to classify as non-words than are pronounceable non-words which do not sound like words and this indicates that phonological recoding is involved in reading.

All of these experiments have demonstrated that phonological recoding occurs even when unnecessary for the task, and suggests that phonological codes are achieved automatically. Rubenstein, et al. (1971) made a claim based on their experiments that phonological recoding is an obligatory stage in gaining access to the lexicon, and hence in gaining access to meaning. They thought that reading is a step by step procedure in which phonological recoding can not be avoided. Coltheart, et al. (1977) replicated the Rubenstein et al. experiments (1971) and obtained slightly different results. Apart from some similar findings, they also found that reaction times to less frequent members of pairs of homophones were no different from the decision times to a set of matched nonhomophones controlled for frequency and part of speech.

This finding implies that while phonological recoding plays a role in reading, it is still doubtful if it is the only route for reading. Coltheart, et al. (1977) emphasize that their finding is not evidence against the view that the access code for lexicon is phonological; it is only evidence against the joint assertion that the code of lexicon is phonological and that the procedure is serial search. Thus they suggest that reading is not a serial *single* route process, rather it is a parallel multi-route process, and phonological recoding plays an important role in one of the routes.

LATERALIZATION IN READING

It has been a well known fact that language function is mainly carried out in one hemisphere of human brain since Broca's time (1865). This is known as the lateralization of language function. As for reading, in the experimental field, a lot of research has been put into this lateralization aspect by studying cerebral hemisphere differences for visually presented material in normal subjects. Such study first drew widespread attention from psychologists by the investigation of Mishkin and Forgays (1952). Since then, the lateralization in reading alphabetic languages has been extensively investigated.

At the time of Mishkin and Forgays (1952), cerebral asymmetry function was not considered as the explanation for the visual performance differences. Internal directional "scanning" strategies arising from habits acquired in learning to read was thought to be the reason for the lateralization phenomenon in

visual hemifield performance, and a few variants of this scanning hypothesis were proposed. However, in the results of a lot of research such a scanning hypothesis has been proved to be inadequate and to have no solid ground as the explanation for performance differences in visual hemifield experiments.

The fact that right visual field advantages are found with right-handed subjects when words are presented in vertical as well as horizontal arrangement can not be explained (Barton, Goodglass and Shai, 1965; Boles, 1985; Bradshaw, Nettleton and Taylor, 1981; Ellis and Young, 1977; Mackavey, Curcio and Rosen, 1975; Mckeever and Gill, 1972; Young and Ellis, 1985). Also, the fact that right visual field advantages are also found in the experiments using words in the Hebrew language for which the reading habit is from right to left can not be explained (Babkoff and Ben-Uriah, 1983; Barton et al., 1965; Carmon, Nachshon and Starinsky, 1976; Orbach, 1967; Silverberg et al.; 1980).

While the scanning hypothesis is not supported by many experiments, the ground for the theory of cerebral asymmetry has been gradually established.

There is some further evidence which supports the theory of cerebral asymmetry. It was found that the right visual field advantage for word recognition is reduced or absent in left handed people, and this can be explained in the light of the theory of cerebral asymmetry (Annett, 1982; Bradshaw, 1980; Hardyck and Petrinovich, 1977; Orbach, 1967; Schmuller and Goodman, 1979). Contrasting with right visual field advantages in verbal tasks,

left visual field advantages are found in non-verbal tasks such as face recognition, and this is can also be explained on the basis of cerebral asymmetry (Ellis, 1983; Hilliard, 1973; Rizzolatti, Umilta and Berlucchi, 1971).

The lateralization in reading is manifested by showing a general right visual field advantage for word recognition. This RVF superiority has been extensively studied. The results show that RVF superiority occurs no matter whether words are presented in a unilateral or a bilateral fashion (unilateral means the word is presented in the left visual field or in the right visual field; bilateral means words are presented both in the left visual field and the right visual field simultaneously), while the way of bilaterally presenting stimuli may increase the size of the right visual field advantage (Boles, 1983; McKeever, 1971; McKeever and Huling, 1971).

Experiments also reveal that RVF superiority is not only evident in the naming tasks but also in the lexical decision tasks (Babkoff and Ben-Uriah, 1983; Barry, 1981; Chiarello, Dronkers and Hardyck, 1984; Hardyck et al., 1985; Leiber, 1976; McKeever and Hoff, 1982).

Although the superiority for words is mainly given to the right vusual field *and the* left hemisphere is thus regarded dominant, this does not imply that the left visual field/the right hemisphere can be neglected. On the contrary, many experiments have shown that the left visual field/the right hemisphere does have some function in dealing with linguistic stimuli. The findings of

visual hemifield asymmetries for identifying letters in unpronounceable strings have revealed many possibilities, ranging from the left visual field advantage (Scheerer, 1974) through to no visual hemifield differences (Coltheart and Arthur, 1971; Smith and Ramunas, 1971) to right visual field advantage (Bryden, 1966, 1970; Fudin and Kenny, 1972; Hirata and Bryden, 1976; Scheerer, 1974). Moreover, research has also shown that the right hemisphere surpasses the left in reading script variants -- e.g. different typefaces (Bryden, et al. 1976).

However, attention should be paid to some inspiring findings: in contrast to the identification of letters and unpronounceable letter strings, whenever pronounceable non-words are used as linguistic stimuli, the results of visual hemifield asymmetry experiments have always led to a right visual field advantage in right-handed subjects (Axelrod, Haryadi and Leiber, 1977; Bryden, 1970; Dornbush and Winnick, 1965; Levy and Reid, 1978; Levy et al., 1983; Young and Ellis, 1985; Young, Bion and Ellis, 1980; Young, Ellis and Bion, 1984). This suggests that the lateralization is closely related to the phonological process of reading. Thus, it further implies that there is actually an agreement between the left hemisphere advantage and the requirement of the phonological process in reading alphabetic words.

1.4.2. ACQUIRED DYSLEXIA STUDIES ON READING ALPHABETIC WORDS

Studies on acquired dyslexia can be divided into two aspects: one is the neuroanatomical study, the other is the cognitive neuropsychological study. The former is mainly carried out by neurologists and the later is mainly carried out by psychologists. The studies on the neuroanatomical aspect of acquired dyslexia have

achieved clinical classifications of various reading disorders, the localization of their lesions and neurological data for setting up the neuroanatomical models of reading. The studies on the cognitive neuropsychological aspect of acquired dyslexia have discovered several different types of reading disorders in the light of cognitive function, the cognitive components in reading processes and the cognitive data for setting up the cognitive neuropsychological reading models.

NEUROANATOMICAL STUDIES

The study of reading disorders by neurologists has quite a long history. It started before the time of Broca. At least there were four reports of reading disorders appeared in this early period. Valevius Maximus in 30 AD was the first person to describe reading impairment. His patient, who after being struck on the head by an axe, lost his memory for letters but had no other defects. Late Mercuriale in 1588, Johann Schmidt in 1673 and Johann A.P.Gesner in 1770 described another three cases of reading disorder (Benton, 1964).

There were not many cases of reading disorder recorded during the time of Broca. Broadbent (1872), Kussmaul (1877) Charcot (1877), Guenean de Mussy (1879) and Bertholle (1881) reported a few patients suffering from reading impairment.

It was not until the end of the nineteenth century that the study of reading disorder was advanced considerably especially by the influence of the work of Dejerine. Dejerine (1891, 1892) published clearly defined cases of reading disorder including

postmortem findings. The reports prompted a rise in interest in dyslexia from neurologists. A few years later Bastian (1898) reported several cases in support of the finding of Dejerine. Hinshelwood (1900) described a series of 28 cases of word blindness. Thus by the beginning of this century the basic picture of reading disorders had been drawn up.

From the beginning of this century more and more cases of acquired dyslexia have been added to the literature. The cases vary in the way the patients appear either as an isolated phenomenon or as a mixed-up syndrome with aphasia or agraphia. There are several comprehensive reviews about such studies. DeMassary (1932) thoroughly reviewed the French contributions. Lange (1936) reviewed the German contributions. Weisenburg and McBride (1935) and Holmes (1950) reviewed English contributions. In eastern European countries, one can see a obvious reflection of the powerful influence of Pavlovian thinking. Cases reported there have been discussed in terms of the defect of primary or secondary visual analyzers (Davidenkov 1956a,b; Luria, 1966).

There are many classifications of reading disorder made by neurologists. There is a long list of the authors and they use many terms to represent the different kinds of reading disorders classified by them. However, the matter can be made easier for it is reasonable to categorise different classifications into a more general one. Benson (1981) has done such work by suggesting the three categories to include and classify different sorts of reading disorders, i.e. the posterior alexia, the central alexia and the

anterior alexia. The neuroanatomical features of the three types of reading disorders are easy to see. The posterior alexia had the lesion located in the posterior medial cerebral cortex, commonly the white matter of the fusiform and the lingual gyri of the dominant occipital lobe. The anterior alexia was caused by the lesions in the posterior inferior portion of the dominant (left) frontal gyrus in most cases, and it is quite common that injuries extended deeply into the subcortical tissues, especially in the anterior insula. The pathology of the central alexia usually involved the dominant parietal lobe particularly the dominant angular gyrus.

There is another important issue in the neurology of reading: the relationship between reading disorders and other language disorders. This is quite a complex issue and so far has not yet been investigated in detail. However, the relationship exists. For a long time, neurologists have found reading disorders often cooccur with writing disorders: i.e. alexia with agraphia, and alexia without agraphia. Studies have also found that reading disorders also cooccur with different kinds of aphasia. Alexic patients can have Wernicke's aphasia (Hier, Gorelick, and Shindler, 1987). Some alexic patients were also identified as Broca's aphasia (Benson, 1977; Boccardi, et al, 1984).

It is obvious that the neuroanatomical reading studies have not given much information on the psychological process involved in reading. They focus on the neuroanatomical structures involved in reading. In recent years, the Wernicke-Geschwind model suggests

that the neuroanatomical mechanism of language consists of the following constructions: Broca's area, Wernicke's area, the arcuate fasciculus (which connects Broca's area with Wernicke's area), the precentral and postcentral face area, the angular gyrus, and the auditory and the visual cortex. As for the reading process, this model proposes a neurological passage: Written word -- Area 17 -- Areas 18,19 -- Area 39 (the angular gyrus) -- Wernicke's area -- Read. This passage emphasises the importance of the angular gyrus which combines sensory information to house "visual patterns" of letters, words, etc., and acts in some way to convert a visual stimulus into the appropriate auditory form. However, the Wernicke-Geschwind model has been criticized for its rigid localizationist bias.

COGNITIVE NEUROPSYCHOLOGICAL STUDIES

In recent years, with the rise of cognitive neuropsychology, the researches by psychologists on reading disorders have become very successful and have turned out to be a dominant trend in studying reading disorders. Focusing on detailed analysis of cognitive functions in reading disorders, several different types of acquired dyslexia have been found. Among them, deep dyslexia, surface dyslexia and phonological dyslexia are regarded important by cognitive neuropsychologists in the sense that they have provided strong evidence for the routes involved in reading. Both deep and surface dyslexia were found in 70's of this century, while phonological dyslexia was a later one. In the following, I will first review these three important dyslexias in a historical way,

and then go to examine some other kinds of dyslexia as well.

DEEP DYSLEXIA

(i) Symptoms:

Deep dyslexia is an acquired reading disorder classified by Marshall and Newcombe (1973).

The critical symptom of deep dyslexia is semantic error (Marshall and Newcombe, 1973). In reading tests, patients of this kind quite often can not pronounce correctly the target words they are asked to read, instead, they make responses with some other words which have semantic relations with the target words. For example, "city" is read as "town", "bush" is read as "tree" (Kapur and Perl, 1978; Patterson and Marcel, 1977). This error can be found in the reading of sentences, but what is even more interesting is that it becomes especially apparent when patients are reading single words (Marshall and Newcombe 1966). The semantic errors can be categorized into several types. The range of these types is from synonyms, e. g. sick -- "ill", to the word pair connected only by sharing one or two semantic features, e. g. bad -- "liar" (Marshall and Newcombe 1966). The incidence of this semantic error in reading single words aloud varies from patient to patient, the range of variations is from about 5 percent in some patients, e. g. KF (Shallice and Warrington, 1975) to about 60 percent in some patients, e. g. GR (Marshall and Newcombe 1966, 1973).

Another important symptom of deep dyslexia is the difficulty in reading non-words. Deep dyslexic patients are found to have

severe difficulty in reading non-words, such as tud, nol, etc. (Marshall and newcombe, 1973, 1980).

Apart from the above two distinguishing features of deep dyslexia, there are some other symptoms which exist in deep dyslexic patients. These are:

Visual errors. Errors of this type are like bush - 'brush', edge - "wedge", was - "wait" (patient P.W. reported by Patterson, et al, 1977). In the patients' incorrect responses, at least half of the letters in the stimulus can be found. Some patients misread words by substituting some words that have similar visual appearance, and this substitution is not a phonological one, such as replacing phonologically similar word with a different "visual form", e. g. phrase -- "freeze".

Derivational errors. These can also be called morphological errors. Errors of this type are like lovely -- "love", drink -- "drinking", rejected -- "rejection" (patient P.W.). In patients' errors, the base lexical item can be found, but the bound morpheme is lost, or added or substituted. Patients misread words as a different part of speech.

Visual-semantic errors. Errors of this type are like question -- "query", leader -- "head", raise -- "rise" (patient P.W.). The incorrect response patients make share both visual and semantic features.

Difficulty in reading function words. In reading tests function words can be found more difficult to read and producing a kind of error, such as on -- "off", my -- "me", his -- "yours"

(patient P.W.). Patients make some substitutions for the function words they are required to read, the patients mistake one function word for an another function word.

Difficulty in reading abstract words. The reading behavior of deep dyslexic patients is influenced by the effects of word concreteness and word imageability. Patients find words like baby, church, table, etc, which are concrete and imageable, easier to read than words like belief, truth, justice, etc, which are abstract in nature (Ellis, 1984).

Circumlocutions. This is a phenomenon in which patients can make a meaning-related response for reading a word when he/she fails to pronounce it, such as edition -- "london, paper, editor"; debt -- "buy, the same"; oxide -- "chemical, oxygen" (patient D.E. reported by Patterson). Moreover, it needs to be noted here that deep dyslexic patients can understand more words than they can read aloud correctly (Coltheart, 1980).

(ii) Theoretical explanations:

Deep dyslexia has caused greater excitement than any other acquired dyslexia. Much research has been stimulated in this field, several theories have been put forward on this issue and more questions have been asked as well. The intriguing semantic paralexia seems to reveal some novel features of reading processes and thus has attracted great attention ever since it was found and classified as the main characteristic of deep dyslexia (Marshall and Newcombe 1966). In general, the existence of deep dyslexia, especially the semantic symptoms is in favour of the multi-route

model. According to the multi-route model, there are at least two distinct routes in reading process, a semantic route and a phonological route. The phonological route is important in pronouncing a word. Many researchers agree that deep dyslexic patients can no longer use this phonological reading route. As a result, the pronunciation become troublesome, hence the inability to read non-words. Since the semantic route remains functional, the semantic error appears. Newcombe and Marshall (1980) conjecture that the semantic system is intrinsically unstable and the phonological reading system acts as a stabilizing mechanism to prevent errors, thus semantic errors of deep dyslexic patients happened as a result of their inability to use the grapheme-phoneme conversion and have an exacerbated amount of instability in their semantic system.

Apart from this general agreement on the multi-route model, there are various explanations for the deep dyslexic syndromes. Morton and Patterson (1980) suggest there are at least five further impairments to account for the constellation of deep dyslexic symptoms. They gave their account for deep dyslexia with respect to their revised logogen model. In this model, a visual word is first of all visually analysed. Then, information can go to the response buffer via grapheme-phoneme conversion or to visual input logogens. From visual input logogens the information can go directly to output logogens, and then to the response buffer or via cognitive system to output logogens. The cognitive system consists of several cognitive mechanisms, ie. a parser, imageable/abstract

semantics, and a linguistic processor. As for deep dyslexia they claim that there is the following damage in the model: 1. the non-lexical grapheme-phoneme route is non-functional. This accounts for the poor or non-existent performance on any non-lexical phonological manipulations. 2. The connection from visual input to output logogens is non-functional. This predicts that the patients should never produce as a reading response a word which they do not at least partially understand. 3. There is a damage to the connection between visual input logogens and imageable/abstract semantics in the cognitive system, particularly to the connection for abstract words. This accounts for the visual paralexias and some semantic errors. Since it is only for some words that the semantic code uniquely identifies one output logogen, abstract words and words with close synonyms will yield semantic paralexias which are unidentifiable as errors. 4. There is a problem in the connection from the imageable/abstract semantic to output logogens. This accounts for some semantic paralexias which the patients can identify as errors. 5. The linguistic processor in the cognitive system is impaired. This accounts for derivational paralexias and function word errors.

Shallice and Warrington (1980) propose that there are two subtypes of deep dyslexia: one has difficulty accessing semantic representations; the other can access semantic constructs but can not name them.

Coltheart (1980) has proposed that the right hemisphere is particularly involved in reading performance of deep dyslexia based

on the following facts: first, the features of deep dyslexic reading coincide with what is known about the reading ability of the right hemisphere; secondly, in deep dyslexic patients there has usually been extensive damage to the left hemisphere. He proposes that deep dyslexia is the result of a lesion which abolishes access from orthography to the left-hemisphere lexicon; therefore reading will require orthographic access to a right-hemisphere lexicon, interhemispheric transmission of semantic information and the use of this information to get an output in the left hemisphere. The symptoms of deep dyslexia are manifested in this abnormal reading processes.

SURFACE DYSLEXIA

(i) Symptoms:

Surface dyslexia is an acquired reading disorder classified by Marshall and Newcombe (1973).

There are two critical or distinctive symptoms of surface dyslexia. One is a specific difficulty in reading irregularly spelled words (Patterson, Marshall and Coltheart, 1985). Patients are more successful at reading regular words where words follow common regular spelling-to-sound rules. A number of errors patients make in reading irregular words look as if they have arisen from the logical application of a rule system. One typical case is that of Bub, Cancelliere and Kertesz (1985). This patient could read regular words quite normally, but made many mistakes in reading irregular words. Nearly all her errors here seemed to regularize pronunciations for those irregular words, for example,

she read "have" as if it rhymed with "cave", "lose" as if it rhymed with "hose", "own" as if it rhymed with "down" and "steak" as if it rhymed with "beak" (Bub, Cancelliere and Kertesz 1985). This kind of reading error is called regularization (Coltheart et al., 1983). Errors of this type sometimes can be nonwords, such as reading "island" as "izland", "recent" as "rikunt"; and sometimes can be other real words, such as reading "disease" as "decease", "guest" as "just", and "phase" as "face" (Marshall and Newcombe, 1973). The difference between the efficiency of reading regular words and efficiency of reading irregular words can be quite large, as in the case reported by Bub et al. and in the case reported by Shallice and Warrington (Shallice and Warrington 1980), in which thirty-six out of thirty-nine regular words were read correctly while only twenty-five out of thirty-nine irregular words were read correctly.

Another important feature of surface dyslexia is homophone confusion (Patterson, Marshall and Coltheart, 1985). Patients are found to have a comprehension problem when their oral response differs from the word presented for reading, their comprehension of the word is determined by the incorrect pronunciation they assign to the word. Therefore, homophones are found to be confused with each other in patients' reading comprehension, such as "soul" was understood as "shoe", "route" was understood as "what holds the apple tree in the ground and makes it grow" (patient A.B. reported by Coltheart, Masterson, Prior and Riddoch, 1983). In another case, "listen" was comprehended as "Liston ... that's the boxer", "begin" was comprehended as "beggin ... collecting money", "omit"

was comprehended as "ommit ... that's the name of the prophet of Islam" (patient J.C. reported by Marshall and Newcome, 1973). There are two kinds of homophone confusion, one is homophone confusion with regular-spelled homophones, such as "route" understood as "part of a tree"; another is homophone confusion with irregular-spelled homophones, such as "bury" -- "a fruit on a tree".

In addition to above two distinctive symptoms of surface dyslexia, there are some other evident reading phenomena: Semantic errors are effectively absent. The same is true for derivational, visual-semantic errors. Non-words are not found harder to read than words.

Apart from these characteristics of surface dyslexia, some other reading symptoms have also been observed. Some patients are found to make visual errors. They misread "tough" as "though", "precise" as "precious", "sing" as "sign" and "foreign" as "forgiven". These errors were reported to be rapidly produced, in contrast to the other, laboriously assembled pronunciations (Holmes, 1973). A "part of speech" effect is found in some patients (Marshall and Newcombe, 1973). Word length has been found to affect ease of reading in some cases in which longer words are found more prone to the production of errors (Temple, 1987). The effects of rated imageability and frequency are observed in some cases, but they are not large (Temple, 1987). Finally, all patients are found to have difficulties in writing and spelling.

(ii) Theoretical explanations:

Like deep dyslexia, surface dyslexia favours the multi-route

model. In contrast to the former, it gives evidence about the other aspect of the reading routes. Surface dyslexia is mainly thought of as the result of impairing the non-phonological route, consequently, reading is basically carried out through the phonological route where a phonological conversion system is an obligatory process and the only one. As a result, regularization and homophone confusions appear. Apart from this general agreement, the opinions of reading psychologists vary since there are differences with regard to the mechanism involved in reading pronounceable non-words, or in the essential details of the phonological conversion system. In main, they can be classified into two groups.

One group of them believes that non-words are read via process of grapheme-phoneme conversion (e. g. Newcombe and Marshall, 1980). The other group believes that non-words are read via a conversion system based upon orthographic units which may be larger than the grapheme, the written representation of a single phoneme (e.g. Shallice and Warrington, 1980). Nevertheless, both of these groups consider that reading is a multiple route process; the way of reading non-words is clearly separate and dissociable from a semantically based mechanism of reading by which real words can be read. The symptoms of surface dyslexia are produced by overreliance on the phonological conversion system which actually is not complete for handling irregularity in spelling-to-sound relationship.

Since the phonological route is intact, non-words are not

found difficult to read. Considering the impairments here are opposite to that in deep dyslexia, what have been found as the critical symptom of deep dyslexia, i.e. semantic errors, are naturally absent.

Marcel (1980) offers a different explanation for the symptoms of surface dyslexia. He analysed in detail the error corpora of the original surface dyslexic patients described by Marshall and Newcombe (1973) and showed that they did not fit the multi-route model. He cited two kinds of evidence from the errors made by the patients to support his opinion. One kind of evidence was that there are many real words in patients' responses. It seems that the patients tended to produce words as responses. He then argued that if their errors arise as a result of the application of grapheme-phoneme rules, why were only a minority of the responses non-words which would be the reasonable responses in terms of multi-route model. If a word like colonel or yacht is regularised, the end result is not generally another word. The other kind of evidence is the errors that are consistently quoted as exemplars of surface dyslexia errors do not fit with the notion of the application of grapheme-phoneme correspondence rules. For example, in the cases like incense -- "increase", or barge -- "bargain", it is very difficult to explain where the "r" in "increase" and "ain" in "bargain" come from in terms of multi-route model. It would appear that the spelling-to-sound relation is embedded in a lexical framework. According to his lexical analogy model, the lexical process is not separated from the other reading systems and there

is only one mechanism for converting print to sound.

PHONOLOGICAL DYSLEXIA

(i) Symptoms:

Phonological dyslexia is the most recently discovered acquired dyslexia type which was first described by Beauvois and Derouesne (1979).

Phonological dyslexia is a reading disorder which is difficult to observe naturally since its critical symptom is in reading non-words rather than real words, so we can not expect it to be found in a natural way. The existence of phonological dyslexia is predictable in terms of the multi-route model. Since deep dyslexia is thought to be caused by impairment in the phonological reading route with some damage also in the lexical reading route, it is therefore quite reasonable to expect to find a reading disorder in which the phonological reading route is disrupted while the lexical reading route remains intact, consequently, a phenomenon of capacity to read words but severely poor at reading non-words will be found. The finding of phonological dyslexia thus confirms this prediction. The existence of phonological dyslexia once again provides strong evidence for the rationale of the multi-route model.

As has already been mentioned above, the critical symptom of phonological dyslexia is the inability to read non-words while reading of real words can be, though not necessarily, normal (Funnell, 1983). This symptom became very apparent when a phonological dyslexic patient was unable to read even very simple

non-words, like "nust", and "cobe" (Funnell, 1983). It seems that phonological dyslexic patients have lost the ability to get pronunciations for non-words from even the most rudimentary spelling-to-sound principles, while however they still keep the capacity of normally reading almost any familiar real words (Patterson, 1982; Funnell, 1983).

Apart from being unable to read non-words, phonological dyslexic patients make two types of errors when they are reading words, one is derivational, e. g. weigh --- "weight", child --- "children"; another is visual, e. g. camp --- "cape", picture --- "patter". The incidence of these derivational and visual type errors varies from case to case (Temple, 1987).

In addition, some phonological dyslexic patients have difficulty reading function words. For example, in the case reported by Patterson, the patient sometimes misread function words like "with" or "then" (Patterson, 1982).

All of the phonological dyslexic patients *that have been found so far do not make the regularization errors when they are reading irregular words.*

Semantic errors as found in deep dyslexia is extremely rare, only one case was reported to have had such error (Funnell, 1983).

(ii) Theoretical explanations:

The critical symptoms of phonological dyslexia, i.e. inability to read non-words, provide strong evidence for multi-route models. It is convincing to regard phonological dyslexia as caused by impairment to the phonological reading route, while the

lexical reading route remains intact. Since reading non-words is the function of the phonological route, the critical symptoms of phonological dyslexia are produced by the damage to this route. This is different from deep dyslexia which also has impairment in the phonological route, but it is in conjunction with some problems in some aspects of the lexical reading route and therefore, semantic errors appeared. Moreover, since the lexical route in phonological dyslexia still remains normal, no severe semantic error happened. Shallice and Warrington (1980) consider phonological dyslexia a single-component syndrome compared with deep dyslexia which is multi-component dyslexic syndrome. They believe that phonological dyslexics have a highly selective deficit involving the assembly of phonology, whereas deep dyslexia requires more than one functional lesion for explanation.

As for the derivational errors and the difficulty in reading function words, Patterson (1982) has explained them in multi-route model by suggesting that function words and affixes are represented as whole units in the phonological route.

Since reading words is almost normal, phonological dyslexia thus proved that when the lexical route is in isolation, it will be able to get correct phonological information for real words.

Phonological dyslexia demonstrates the impairment of the phonological route and provides an opportunity to observe the behavior of the lexical route in isolation.

Barry and De Bastiani (1985) have tried to use the lexical analogy model to explain phonological dyslexia. Their opinion is

based on the experimental results obtained by Bradley and Thomson (1984). In an experiment, Bradley and Thomson found the performance of reading non-words of their phonological dyslexia is influenced by lexical information. Although only able to read 13 per cent of non-words, when presented with a familiar word (one letter of which was circled) and asked to pronounce the non-word produced by the deletion of the circled letter, the performance of their patient rose to at least 50 per cent. Barry and De Bastiani believe that these results fit lexical analogy theory presuming that a lexical analogy procedure operates on the basis of simply producing the most common correspondence of orthographic segments as they occur in words. However, there is evidence against the lexical analogy theories as explanations of phonological dyslexia. Funnell (1983) found her phonological dyslexic patient was able to find and pronounce words embedded in non-words (e.g. *alforsut*), and this indicates that orthographic segmentation was intact.

Deep dyslexia, surface dyslexia and phonological dyslexia are the types of acquired dyslexia which have importance in setting up a cognitive reading theory--the multi-route model. Apart from these, there are some other types of acquired dyslexia found in the field of cognitive reading studies. They include: letter by letter reading, attentional dyslexia, visual dyslexia, and non-semantic reading. Different from deep, surface and phonological dyslexia, they, however, have less significance in the light of the multi-route models. Some of them have significance in neuroanatomic sense, and some of them have significance in some other aspects of

cognition function of reading.

LETTER-BY-LETTER READING

(i) Symptoms:

The distinctive characteristic of letter-by-letter reading is just as the term indicates: the reading behavior of patients manifests in a peculiar letter-by-letter manner. When patients are reading a word, the letters of the word will usually be named aloud, from left to right, quite slowly especially in the cases where the word being read is long. By the time they arrive the end of the word having named all the letters correctly, the word then is likely to be read aloud correctly. The number of letters in a word or non-word is a major stimulus property which will affect the reading ability of patients: short words/non-words can be read well, while long words/non-words are read badly and very slowly (Patterson and Kay, 1982). Patients often have no problem in identifying letters but can not read a word without first identifying each letter in the word. Therefore letter-by-letter reading is also called word-form dyslexia (Warrington and Shallice, 1980).

Letter-by-letter reading as a compensatory strategy used to be called pure alexia or alexia without agraphia. It is so named because it is the only variety of acquired dyslexia in which spelling and writing usually are intact, whereas all the other kinds of acquired dyslexia typically have impaired writing and spelling as well as impaired reading. However, even though letter-by-letter readers can usually write a perfect passage, they are

unable to read what they have just written.

As pure alexia or alexia without agraphia, letter-by-letter reading was actually discovered quite early, by Dejerine (1892). Further studies on this acquired dyslexia appeared in neurological literature (Geschwind, 1962, 1965; Greenblatt, 1976; Vincent, Sadowsky, Saunders and Reeves, 1977).

(ii) Theoretical explanations:

Letter-by-letter reading seems to provide more information on the neuroanatomical features than on the cognitive features. Letter-by-letter patients have been found to have a blockage between the visual cortex and angular gyrus. Thus a word perceived to the visual cortex can not be transfer to the angular gyrus directly but have to go through auditory route to the language area in the temporal lobe. Once the patient pronounced all the individual letters in a word, then the whole word is understood through the sound system and it is consequently read. Therefore, letter-by-letter reading demonstrates importance of the connection between the visual cortex and the angular gyrus in reading and this disconnection syndrome has led to establishment of the neurological model of reading disorders (Dejerine, 1892; Geschwind, 1962, 1965).

In order to investigate the cognitive features of letter-by-letter reading, Warrington and Shallice (1980), Patterson and Kay (1982) carried out detailed studies on this kind of patients. They arrived at similar conclusions: The impairment is early in the reading process. Two hypothesis have been put forward to locate the damage. Patterson and Kay (1982) suggested that the damage has

been incurred to the transmission of information from letter-form analysis systems to the visual logogen or visual word-form system. The evidence is that enormous effort was required for their patient to identify letters. Warrington and Shallice (1980) suggested that the damage is located in the visual word-form system itself. The evidence is that their patients' explicit letter identification was more accurate and rapid. Letter-by-letter reading compensates for loss of word-forms. Thus further investigation of patients is needed to clearly establish which precise part of the reading process has been impaired.

ATTENTIONAL DYSLEXIA

Attentional dyslexia was defined by Shallice and Warrington (1977). The main characteristics of this kind of acquired dyslexia are: (1) Patients make a great many 'visual segmentation errors' when shown groups of words even under the condition in which unlimited time was given to them for viewing the words. (2) Patients have difficulty naming letters in strings but not letters in isolation. The cause of this attentional dyslexia seems to be the impairment of the visual analysis system/or its connections with the visual word recognition system (Shallice and Warrington, 1977).

VISUAL DYSLEXIA

Visual dyslexia is characterized by making frequent visually based errors in word recognition. Patients can sometimes name all the component letters of the word to be recognized, but still make visual errors. Visual dyslexia would appear to indicate 'slippage'

within the visual word recognition system (Marshall and Newcombe, 1973; Newcombe and Marshall, 1981).

NON-SEMANTIC READING

The characteristic of Non-semantic reading is that patients can read words but not understand the meaning (Schwartz, Marin, and Saffran, 1979; Schwartz, Saffran and Marin, 1980; Shallice, Warrington and McCarthy, 1983). Non-semantic reading may suggest that the visual word form (visual input logogen) can activate in some direct fashion an associated representation in a phonological lexicon (output logogen) (Schwartz, Saffran and Marin, 1980).

1.4.3. STUDIES OF DEVELOPMENTAL DYSLEXIA IN ALPHABETIC

WRITING SYSTEMS

Developmental dyslexia has been a public concern for a long time. Generally speaking, 5 % to 10 % of school children have developmental dyslexia (Tarnopol, L. et al. 1981). It is impossible to list all the achievements on studies in this field. To meet the requirements of my study, I will review some of the main aspects of the cause and the mechanisms of developmental dyslexia already known.

VISUAL PROBLEMS

The idea that visual problems are regarded as the cause of developmental dyslexia has occupied a dominant position in the history of this study. Many cases of reading problems were consistently interpreted in terms of problems of visual memory and perception by pioneers such as Hinshelwood (1895, 1917) and Orton (1937). The point of this idea is that there might have some

generalized weaknesses in perceiving and remembering visual patterns like words, and it is clear that if such weaknesses did exist it would provide a good explanation for difficulties in learning to read. However, most research focused on testing this idea has provided evidence that this is not the case. For most developmental dyslexic readers, problems of visual perception and memory are not the cause of their problems (Hulme, 1981; Jorm, 1983; Vellutino, 1979).

HEMISPHERE DIFFERENCES

Quite a lot research has been oriented towards finding out whether hemisphere difference is the cause for developmental dyslexia. As some common symptoms, such as letter reversal, orientation confusion, and general delay in language development, indicate it is reasonable to think that developmental dyslexia may have a not-well-lateralized hemisphere function. However, in terms of the simple relationship between laterality and dyslexia the literature is not at all clear. Some studies show higher incidences of mixed handedness or cross-laterality amongst reading disabled children (Bryden, 1970; Critchley, 1970; Zangwill, 1962; Naidoo, 1972; Keefe, 1976; Farr and Leigh, 1972; Newton, 1970; Wheeler, 1978). While, on the other hand, some research presents evidence that disagrees with the relationship between the above variables and reading failure (Hardyck and Petrinovitch, 1977; Clark, 1970; Rutter et al. 1970; Hardyck, 1977; Goldberg and Shiffman, 1972). Nevertheless, on the whole, some forms of mixed laterality do appear to be associated with developmental dyslexia.

SEX DIFFERENCES

Much research has showed that developmental dyslexia is much more common in boys than in girls. Critchley (1970) suggested a 4 to 1 ratio of boys to girls. Money (1966) suggests 2 to 1. Rutter et al. (1970) 3.3 to 1. Naidoo (1972) 5 to 1. Although the frequency varies, the sex difference in developmental dyslexia is well established.

However, the reason for the sex difference is debatable. There are explanations in terms of (1) a greater developmental maturity at the age of 6, (2) greater incidence of cerebral trauma in males, (3) greater motivation of females in the learning situation, and (4) secondary emotional conflict in the male associated with factors (1) and (3) (Goldberg and Schiffman, 1972). Apart from the above explanations, there is also the opinion concerning the difference in the way boys and girls react to social interaction and enviromental factors (Moseley, 1972; Kellmer-Pringle, et al. 1966). Another interesting possibility for the sex difference in developmental dyslexia relates to the hemisphere function. The point here is that the right hemisphere is generally responsible for visual-spatial functions and some observations have shown that boys tend to be rather better at visuo-spatial functioning while girls are much better than boys at verbal skills (Maccoby and Jacklin, 1974). An interrelationship between left-hemisphere specialism for language and right-hemisphere specialism for visuo-spatial function is linked in some way to the sex difference in developmental dyslexia.

PHONOLOGICAL AWARENESS

There is a good deal of evidence that phonological awareness is linked with learning to read. Liberman et al. (1977) showed that performance on the phoneme segmentation task before learning to read correlated with later reading ability. Bradley and Bryant (1978) showed that retarded readers have difficulty in categorizing words on the basis of their sound. Lundberg, Olofsson and Wall (1981) found a battery of measures of phonological awareness were predictive of reading scores a year and half later. Similarly, Stanovich, Cunningham and Cramer (1984) found that a battery of measures of phonological awareness administered before starting to learn to read predicted success in reading on year later. It is quite reasonable to link the problem of phonological awareness with the difficulty in learning to read. The problem in phonological awareness will block the development of phonic skills because the child will be unable to see the connection between the way words sound and the way they are spelt.

DEVELOPMENTAL DYSLEXICS HAVE DIFFICULTY IN MASTERING THE PHONIC ASPECT OF READING

There is a good deal of evidence that developmental dyslexic readers have particular difficulty in mastering the phonic aspects of reading. Some studies have showed that developmental dyslexic readers have difficulty in reading non-words, which presumably depends upon the application of phonic rules for their correct decoding (Snowling, 1981; Olson et al., 1985). Some studies have showed that retarded readers are less sensitive to the effects of

spelling-to-sound regularity than normal readers of the same reading age (Frith and Snowling, 1983). This evidence implies that an underlying weakness in phonological awareness may be an important factor in causing developmental dyslexia. Moreover, there is evidence which shows the effects of phonological training on learning to read. A group of children with poor language awareness were trained by Bradley and Bryant (1983) to be aware of sounds in two years by a method in which children were required to select which of a set of pictures of common objects had names with the same beginning (e.g., hen, hat), middle (e.g., hen pet) or final (e.g., hen, man) sounds. It was found that at the end of the training these children were reading better than a group given no special training. This study provide evidence that phonological awareness can help children to learn to read.

DEVELOPMENTAL DYSLEXIA MAY BE THE ARREST OF DEVELOPMENT AT A PARTICULAR STAGE

Frith (1985) suggested a developmental framework of reading in which developmental dyslexia is viewed as a persistent failure to advance to the next step in the normal acquisition process. She assumed that for reading there is a developmental sequence of steps with new reading strategies introduced at different points in the sequence. She proposed that the development of reading is divided into three phases identified with three strategies called "logographic skills" (referring to the instant recognition of familiar words), "alphabetic skills" (referring to knowledge and use of individual phonemes and their correspondences, and phonological

factors play a crucial role in these skills) and "orthographic skills" (referring to the instant analysis of words into orthographic units without phonological conversion). A step forward in the sequence is identified with the adoption of a new strategy. She claimed that developmental dyslexia is the failure of acquisition of alphabetic skills in the normal developmental sequence.

TYPES OF DEVELOPMENTAL DYSLEXIA WHICH MAY COMPATIBLE WITH ACQUIRED DYSLEXIA

Considering the different types of acquired dyslexia, some psychologists have asked whether there are some similar types of developmental dyslexia. Despite the difference between acquired dyslexia and developmental dyslexia in the sense that the former has a known brain injury and the later has not, the studies on this comparison have indeed given some parallel evidence between them.

DEVELOPMENTAL DEEP DYSLEXIA

Jorm (1979) claims that there is a similarity between developmental dyslexia and deep dyslexia. His opinion is based on two facts: One is the similarity when it comes to reading nonwords like 'blint' aloud. From the work of Snowling (1980, 1981), Seymour and Porpodas (1980), we know that when it comes to reading nonwords, developmental dyslexics are slower and less accurate even than younger, normal children with the same reading age as the dyslexics. Another fact is the similarity that both deep dyslexia and developmental dyslexia are better at reading imageable words aloud than abstract words.

However, some authors disagree with Jorm's opinion on these two points. As Baddeley, Ellis, and Lewis (1982) point out, although developmental dyslexics are undoubtedly inefficient at reading nonwords, they are not totally incapable in the way acquired deep dyslexics are. Moreover, they also showed that the superiority for imageable words extended to normal children as well. Finally, there is another important problem concerning the similarity between deep and developmental dyslexics. It is a question of whether semantic errors occur in developmental dyslexics. Wells (1906) reported a case who apparently made semantic errors such as misreading "corn" as "wheat", "locomotive" as "engive", and "dog" as "cat". However, it is not sure *that the child* made these errors when reading words presented in isolation. And it is known that normal skilled readers and children also made semantic errors when reading connected text aloud. Thus, one can not judge the similarity between deep dyslexic and developmental dyslexic based on the errors made by the developmental dyslexics in text reading (Critchley and Critchley, 1978). However, there was a case reported by Johnston (1983) which shows a close similarity to deep dyslexia by a number of semantic errors made in reading singly presented words. But, this case had suffered from a head injury when young, therefore it is still not a very convincing case since we require a case in which no relevant brain injury occurred. In short, the status of developmental deep dyslexia is still doubtful. Nevertheless, research on the aspect is suggestive to further study.

DEVELOPMENTAL SURFACE DYSLEXIA

Holmes (1973) was the first to draw an explicit parallel between a kind of developmental dyslexia which is similar to acquired surface dyslexia. In her study, four cases were reported. All of them made regularization errors when they were reading single words. Following Holmes work, research on this kind of developmental disorder has been published by several authors (Coltheart, Masterson, Byng, Prior and Riddoch, 1983; Job, Sartori, Masterson and Coltheart, 1984; and Seymour and MacGregor, 1984).

In the case reported by Coltheart et al. (1983), the same sorts of oral reading errors as usually happened in acquired surface dyslexia, i.e. regularization, were evident. The child was significantly worse at reading irregular words (67 percent correct) than regular words (90 percent correct), and the regularization errors were common in her reading of irregular words. Apart from regularization errors, she also made numerous homophone confusion errors in homophone reading test. This type of developmental reading disorder is expected if someone's reading relies mainly on phonological reading. Thus, the existence of this developmental dyslexia is consistent with the reading model supported by acquired surface dyslexia. Moreover, this type of developmental dyslexia demonstrates the necessity of developing a lexical route in learning to read.

DEVELOPMENTAL PHONOLOGICAL DYSLEXIA

Temple(1984) and Temple and Marshall (1983) have found a kind of developmental dyslexia which shows a similar symptoms to

acquired phonological dyslexia. The cases described by Temple and by Temple and Marshall were particularly poor at applying letter-sound rules to read aloud non-words. Thus, this kind of reading disorder has been termed as developmental phonological dyslexia. The cases similar to this developmental dyslexia have also been described by Seymour and MacGregor (1984), and also by Campbell and Butterworth (1985). The existence of developmental phonological dyslexia is also consistent with the reading model support by acquired phonological dyslexia. Moreover, this type of developmental dyslexia demonstrated the necessity of developing a phonological recoding skill in learning to read.

1.4.4. SUMMARY OF STUDIES ON READING ALPHABETIC LANGUAGES

From the above review on studies of reading alphabetic languages, we can draw the following general conclusions: 1. In the experimental field, phonological recoding has been generally confirmed. Moreover, a lateralization in reading words which is characterized by a right-visual field advantage has been generally obtained, and this left hemisphere superiority seems to be the basis for the phonological process of reading alphabetic words. 2. In the clinical field, several different types of acquired dyslexia have been found through a cognitive neuropsychological approach. Of them, deep, surface and phonological dyslexia have presented strong evidence for setting up the foundations of the multi-routes reading model. 3. In the developmental dyslexia field, various aspects of this disorder have been investigated and the results of this study emphasise the importance of phonological awareness in

the development of reading. Thus, we get a general picture of reading process from the three relevant aspects of reading research, and the core of this picture is a multi-routes framework.

However, as we have already mentioned, there are different sorts of writing system in the world. Some of them are actually not alphabetic. Naturally, a question arises here: are the same reading processes used for non-alphabetic scripts? or do the reading processes depend on the writing system? We will examine this question in the following.

1.5. SCRIPT EFFECTS IN READING

1.5.1. EXPERIMENTAL READING STUDIES

DIFFERENCES IN READING PROCESSES

Two kinds of experiments comparing within-subjects reaction times for Kanji and Kana stimuli have showed that reading processes for Kanji might be different from that for Kana.

STROOP TESTS

Morikawa (1981) used kanji and Kana to examine the Stroop effects. The results showed Japanese subjects reliably exhibit greater interference for naming ink colors of Kanji Stroop stimuli than of Kana Stroop stimuli. The similar results have also been found in some other experiments (Fang, Tzeng & Alva, 1981; Hatta, 1981). Morikawa explained this Stroop effects difference in terms of the difference between two kinds of scripts. Moreover, he claimed that both Kanji and colors are processed by right hemisphere and thus a greater interference happens, while Kana is processed in the left hemisphere and thus less interference occurs

(1981).

NAMING LATENCY STUDIES

Studies on naming latency comparing different scripts have demonstrated that naming latencies are shorter for words transcribed into Kana than for the same words written in Kanji (Feldman, *et al.* 1980). Besner and Hildebrandt (1984) further found words normally written in kana take less time to name than kana transcriptions of kanji words. Since Kanji characters usually have two readings (the On-reading and the Kun-reading), comparative studies were made on these two readings (Nomura, 1978, 1979. reported by Paradis, *et al.* 1985). The results showed that subjects named Kun-readings of single kanji faster than On-readings. This is probably due to a frequency effect, i.e. Kun-readings tended to be of a higher frequency than the On-readings.

LATERALIZATION

Studies on this aspect have provided some evidence for different lateralization in processing different scripts in Japanese writing (kanji and kana), but the results are more contradictory than consistent.

Hatta (1977) found Kanji was better recognized by Japanese subjects in the left visual field and Kana in the right visual field. In a perceptual discrimination experiment, he also found a left visual field advantage for kanji (1981, reported by Paradis *et al.*). In a recognition experiment, Hatta (1976) presented pairs of single kana characters successively to opposite visual fields. Subjects made fewer errors when the first member of the pair was

presented to the right visual field. Sasanuma, Itoh, Mori, and Kobayashi (1977) found a right visual field advantage for pairs of unrelated Kana, but no significant visual field difference for pairs of nonsense kanji. In a perceptual discrimination experiment, Sasanuma, Itoh, Kobayashi and Mori (1980) found no visual field differences with an error rate measure for kana and for kanji.

1.5.2. ACQUIRED DYSLEXIA STUDIES

It is very important to realize the fact that in acquired dyslexia that there exists a script dependency phenomenon. This phenomenon has shed light upon the study of acquired dyslexia and enabled further exploration of universal mechanisms of reading processes.

This script dependency phenomenon manifests itself in three ways:

A: NUMBER VS WORDS

Dejerine (1891) made a prediction in his analysis of "pure alexia" that there should be cases in which patients would retain the ability to read numbers despite their inability to read words since reading numbers is a symbolic activity while reading words is a verbal activity.

Dejerine's prediction was proved correct just few years later by clinical observations. Hinshelwood (1899) found five patients who could read numerals fairly well but could not read individual letters.

In recent years, some similar observations were presented by other researchers (cf. Benson & Geschwind, 1969; Luria, 1970).

B: LOGOGRAPHIC NUMBER VS NON-LOGOGRAPHIC NUMBER

There was a study which showed the script effect for different types of numbers. A research on a letter-by-letter reader of English carried out by Hecaen and Kremin (1976) revealed that the patient read numbers better when they are logographs, like 1, than when they are not, as one. This suggests that there might be a further difference in reading logographic word and reading alphabetic word. Takahashi and Green conducted an experiment on Numerical Judgments with Kanji and Kana by native Japanese speakers (1983). They found the RT function for numerical distance is somewhat different for the two scripts. This result suggests that Kana characters either access a different numerical representation from Kanji characters, or invoke different procedures for comparing the two numbers.

C: KANJI VS KANA

Studies on Japanese patients showed that there was a selective impairment in reading reading Kanji (Chinese characters adopted by Japanese) and Kana (a phonetic syllabic script). In a case of alexia with agraphia without significant auditory language impairments, Yamadori (1975) found that Kana reading was much more severely disrupted than Kanji. Some similar patients who had much better performance in reading Kanji than in reading Kana have also been found (Kotani, 1935; Anzai, et al., 1965; Hayashi, et al., 1985; Nishikawa, 1973; Sasanuma, 1974 , 1980; Yamadori, et al., 1975). On the other hand, some patients were found to have much

better performance in reading Kana than in reading Kanji (Sato, et al., 1971; Inasaka and Kurachi, 1972; Kurachi, et al., 1978; Sasanuma, 1980, 1984, 1985; Yamadori, 1986).

Based on this dissociation between reading Kanji and Kana, a kind of deep dyslexia and a kind of surface dyslexia have been classified (Sasanuma, 1980; Hayashi, et al., 1985; Sasanuma, 1984). A Japanese deep dyslexia reported by Sasanuma (1980) was found to have a clear dissociation in reading performances which showed a more severe impairment in Kana than in Kanji. She read very badly with words in Kana and words with a low concreteness value, and with words belonging to a syntactic class other than concrete nouns, i.e. verbs, adjectives and function words. The errors made by the patient when reading Kanji were dominantly semantic in nature. This type of deep dyslexia in Japanese readers has also been reported by Hayashi, et al. (1985). Their patient showed semantic errors in reading Kanji and was especially poor when reading Kana aloud. No Kana words were read correctly and only one or two individual Kana characters could be read. However, in contrast with Sasanuma's patient, Hayashi's patient was found to have a good comprehension of Kana, as assessed by Kana/picture matching. In contrast to this Japanese deep dyslexia, the cases of Japanese surface dyslexia have also been reported (Sasanuma, 1980, 1984). Sasanuma reported a contrasting case in the same paper (1980). This patient was found to retain quite well his ability to read Kana words aloud, including function words, with no concreteness/abstractness effect or syntactic class effect being

observed. On the other hand, the patient's ability to read Kanji words was clearly impaired. He was found to exhibit a syntactic as well as a weak concreteness/abstractness effect. He made many errors in reading Kanji but they were mainly target unrelated with only a small number of visual and semantic mistakes. Another case of Japanese surface dyslexia reported by Sasanuma (1984) also had a selective impairment in reading Kanji aloud. Further reading tests including lexical decision and comprehension of single words in Kana and Kanji revealed similar symptoms as the previous one. In both cases the Japanese surface dyslexia have been found no regularization errors in reading Kana aloud. This is expected when considering the fact that Kana has a very regular spelling-to-sound system. The basic assumption used for judging Japanese deep dyslexia and surface dyslexia is that Kanji reading is a lexical process, while Kana reading is a non-lexical process. Thus, impairment of reading Kanji is analogous to surface dyslexia, and impairment of reading Kana is analogous to deep dyslexia. This, however, is quite debatable. One obvious reason is that the details of the process of reading Kanji have not been sufficiently examined so far, and Kana does not map onto single phonemes.

1.5.3. DEVELOPMENTAL DYSLEXIA STUDIES

A research on Japanese developmental dyslexia provides evidence for script differences in this issue. Makita (1968) conducted a survey on reading disability in Japanese children. The study indicated that the prevalence of dyslexia in Japan (0.98 %) is some ten times lower than in Western countries. He attributed

the low incidence of Japanese developmental dyslexia to special features of the writing system, which constitutes the most potent factor in the formation of reading disability.

1.5.4. SUMMARY OF SCRIPT EFFECTS ON READING

From the above review, we can see that there are some effects of script on the reading process. In experiments on normal subjects, differences in stroop effect and naming latency for different scripts has been found. Moreover, a difference in the lateralization has also been revealed in reading different scripts. In clinical observation, a discrepancy of reading different scripts has been demonstrated. What is more important here is that some analogies to alphabetic acquired dyslexias, i.e. deep and surface dyslexia, have been reported in Japanese patients in which Kanji was regarded as read by a lexical route, while kana was regarded as read by a phonological route. In the survey of developmental dyslexia, a low ratio of developmental dyslexia has been revealed. These studies mainly reveal the differences between alphabetic words and non-alphabetic scripts and they are primarily based on Japanese studies. As for the three key issues in reading mentioned before, these studies seem to indicate that we might find some language specific feature of reading. Especially with respect to Japanese acquired dyslexia studies in which reading kanji and kana seem to involve different routes. However, there is a critical question for these script differences: can these script differences be so big that reading different writing system is carried out in entirely different ways? This key point needs to be examined in

further studies. Since Japanese kanji are closely linked to Chinese characters, and on the other hand, Chinese characters are the pure case of non-alphabetic script which has some important differences from kanji (such as Chinese characters have not got a complex pronunciation system as that in kanji), studying Chinese characters is undoubtedly a vital step toward answering the above questions. On the whole, the script effects revealed from these non-alphabetic language research provided us a clue for further exploration of this aspect in the study of reading Chinese characters.

1.6. STUDIES ON READING CHINESE CHARACTERS

For the sake of comparison, I will review the studies on reading Chinese characters in the same three categories as I have done with the studies in reading alphabetic languages. Therefore this review is divided into: (1) experimental studies on reading Chinese characters; (2) Chinese acquired dyslexia studies; and (3) Chinese developmental dyslexia studies.

1.6.1. EXPERIMENTAL STUDIES ON READING CHINESE CHARACTERS

Like the experimental studies on reading alphabetic languages, one area is phonological recoding in reading Chinese characters, another is lateralization in reading Chinese characters.

Chinese characters have no formal spelling-to-sound organization in their structure. This allows us to explore some important aspects of the rule of phonological recoding in reading.

PHONOLOGICAL RECODING IN READING CHINESE CHARACTERS

Owing to the characteristics of Chinese characters, the issue

of whether or not there is phonological recoding in reading Chinese characters has become a very important aspect in studying the processes of reading Chinese characters. However, the results of this research are not consistent. Moreover, some studies on the phonological aspect on dealing with Chinese characters were not directly about reading, but actually were memory tests.

Some early research on the psychology of Chinese suggests configuration is more important than phonology when one is dealing with Chinese script. The very first experimental study on the psychology of Chinese characters was carried out by Liu Tinfang in 1921 (Liu, 1923, 1924). In his experiment, the influence of character's configuration on memorising the character's meaning was compared with the influence of character's sound on memorising the character's meaning. The results revealed that the influence of character's configuration on reader's memories of character's meaning was stronger than the influence of character's sound on reader's memory. In 1923 and 1924, Ai Wei conducted further experiments to examine the differences in memorizing two kinds of association established in the process of learning Chinese characters: one is the association between configuration and meaning, the other is the association between configuration and sound (Ai, 1948). The results showed that in the process of learning Chinese characters, the two associations, were simultaneously formed. But, a significant difference in strength existed between these two associations. In the experiments, the subjects were tested two weeks after they finished the procedure of

learning target characters. It was found (when testing) that the subjects could recall the meaning from the configuration more easily than recall the sound from the configuration. This indicated that the association between configuration of characters and the sound of characters deteriorated sooner than the association between the configuration of characters and the meaning of characters.

Some other early research has suggested that Chinese characters have a quite direct route to their meaning.

There was a study comparing the memory of characters' meaning with the memory of characters' sound. Yang jiben (1944) did a memory experiment and found that the sound of a character was more difficult to recognize and maintain than the meaning of a character.

As we see, the above studies were not directly reading experiments but they showed the importance of configuration in dealing with Chinese characters. In contrast to these, there have some memory studies which emphasised the other aspects. Zheng shaoming (1978) carried out an experiment to test whether there is a phonological effect in memorising Chinese characters. The experiment used two lists of characters as stimuli, one was constructed with characters which had distinguishing pronunciations; the other was constructed with characters which had similar pronunciations. The subjects' task was to remember the characters in these two lists. The results showed that subjects had a better memory for the list of characters which had

distinguishing pronunciations than for the list of characters which had similar pronunciations. Mae (1976) also found a tendency to make phonological confusion errors in memorising Chinese characters. Yik (1987) found evidence of both visual and phonological confusions in memorising Chinese characters.

In a genuine reading study, So et al (1977) found that whereas in English the word "pineapple" takes longer to be classified as a fruit than a picture of a pineapple, the Chinese character can be classified as fast as the picture. This experiment does not mean that processing Chinese characters is the same as processing pictures, but it implies that Chinese characters have more direct access to their meanings than alphabetic scripts have.

In a Stroop experiment, Biederman and Tsao (1979) found more interference from Chinese characters than English. They interpret this as showing that Chinese characters allow a more direct access to meaning than alphabetic script does.

Some other studies have also been in favour of a quite direct route to meaning for Chinese characters. Liu kaishen et al (1977) found that silent reading for Chinese numerical words is faster than for German numerical words. Li yongxian (1981) compared the reaction times in judging positive or negative meaning between that of Chinese characters and that of English words, they found that the reaction time for Chinese characters is shorter than that for English words.

Although the above studies emphasize the importance of

configurational properties of the script in dealing with Chinese characters, and demonstrate a quite direct route to meaning of Chinese characters, there have also been some studies which suggest the existence of phonological recoding in reading Chinese characters.

In their first experiment, Tzeng, et al (1977) presented subjects visually with a list of characters, then they were presented aurally with some interfering words. The subjects' task was to remember the visually presented characters. There were three kinds of relationship between the visually presented characters and the spoken words: one had the same consonant, one had the same vowel, and one had both the same consonant and the same vowel. The results of their experiment revealed that the phonological similarity between the visually presented characters and the spoken words influences the ability to remember characters, and the vowel similarity has greater influence than has consonant similarity. In their second experiment, two kinds of sentences were used, one was in keeping with grammar and meaningful, another was not in keeping with grammar and not meaningful. The characters used in these two kinds of sentences had different phonological similarities. Altogether four sorts of sentences were presented to subjects: one sort was meaningful and grammatical sentences constructed from characters with similar pronunciations; one sort was non-meaningful and non-grammatical sentences constructed from characters with similar pronunciations; one sort was meaningful and grammatical sentences constructed from characters with dissimilar

pronunciations; one sort was non-meaningful and non-grammatical sentence constructed from characters with dissimilar pronunciations. The subjects' task was to make a judgement on whether or not the sentence is meaningful. The result of their experiments showed that the degree of phonological similarity among characters in the sentence had a significant influence on subject's judgement; whether the sentence was meaningful and grammatical or not had no influence on subject's judgement. These two experiments indicate the existence of phonological recoding in dealing with Chinese characters.

Cheng chaoming, et al (1988) carried out three experiments to test the possibility of phonological recoding in Chinese using lexical-decision paradigms. The results also showed that in reading Chinese characters a phonological recoding occurs. In their first experiment, the subjects were required to judge, on each test trial, whether or not a visual target which was presented after another character serving as a cue, is a legal character. The outcome indicated that the lexical decision of a target character benefits from the prior presentation of a homophonic character cue and suffers from that of a phonologically-dissimilar cue. Moreover this effect was found to be independent of the visual similarity between the cue and the target. In their second and third experiments, visual target items which were separated by a prescribed stimulus onset asynchrony (SOA) were sequentially presented for lexical decision. The results show a phonological-similarity effect at both short and long SOAs. This effect was

interpreted as having been caused by two priming mechanisms: the spreading of activation and encoding bias. This result was regarded as consistent with the conception that there is phonological recoding in reading Chinese characters.

Moreover, there is evidence which implies the possible manners of phonological recoding in reading Chinese characters. Seidenberg (1985) compared the naming times for pictophonetic characters whose pronunciation was similar or identical to that of their phonetic radicals, and naming times for non-pictophonetic characters, for characters of high or low frequencies of usage. Seidenberg found naming times were faster for pictophonetic characters, but only for low familiarity characters and not for high familiarity characters. Seidenberg took this to mean that for familiar characters, getting at the sound is through character-as-a-whole to sound-as-a-whole information. But with less familiar words, getting at the sound is by a kind of "grapheme-to-phoneme conversion" which uses the phonetics.

LATERALIZATION IN READING CHINESE CHARACTERS

As mentioned before, it is very important to see if there is a hemisphere asymmetry in reading Chinese character due to the fact that they are very different from alphabetic languages in their structures. The results in this field have turned out to be a complicated matter since they are more contradictory than consistent. The studies in this field can be divided into single characters studies and compound characters studies. From the single characters, three kinds of experimental results have been

obtained. (1) RVF-LH advantage. Zhang and Peng (1984) conducted a lateralization test and found a right visual field advantage for reading single Chinese characters. (2) LVF-RH advantage. Tzeng, et al. (1978) reported a study on reading Chinese single characters which showed a left visual field advantage for two types of single characters: one type contains phonetic radicals, the other type is pictographic in origin. (3) No visual field difference. Huang and Jones (1980) found no visual field difference for reading Chinese single characters. Hardyck, Tzeng and Wang (1977) found no visual field difference in a decision task for Chinese single character by bilingual subjects. In another experiment, Hardyck, Tzeng, and Wang also found no visual field difference for reading Chinese single characters.

In compound word studies, the results seem to be similar: a right visual field advantage has been found for reading words which are constructed with two characters. Kershner and Jeng (1972) tested Chinese-English bilingual Taiwanese graduate students in the U.S. using two-character Chinese words and found the stimuli were better seen in the right visual field. Zhang and Peng (1984) tested Mandarin speakers in Mainland China and found a left hemisphere advantage for both single Chinese character and for pairs of Chinese characters. Tzeng, et al. (1979) found a left hemisphere advantage for pairs of Chinese characters vertically arranged. Tsao, Wu, and Feustel (1981) found the two-character Chinese words presented in the right visual field was obtained a faster response in pronunciation than that in the left visual

field.

1.6.2. CHINESE ACQUIRED DYSLEXIA STUDIES

There has not been much research in this field compared with what has been done on acquired dyslexia in alphabetic languages. The very first study of Chinese acquired dyslexia was published in 1938 by Lyman et al. (1938) in Beijing. After that, several clinical reports also appeared in Mainland China (Wang, et al.1959; Tang,1978; Wang, et al.1981; Hu,et al.1983; Li, et al.1984; Hu,et al.1986). There have been very few clinical reports on Chinese acquired dyslexia outside China. These studies on Chinese acquired dyslexia mainly concentrated on the following 4 respects: (1) The neurological anatomy of Chinese acquired dyslexia. The studies determined that the lesions which caused Chinese acquired dyslexia were usually located in the conjunctive areas of the parietal, temporal and occipital lobes in the left hemisphere. This finding is consistent with what has been found in acquired dyslexia in alphabetic languages (Lyman, et al.1938: Wang, et al. 1959; Tang, 1978; Hu, et al. 1983; Li, et al. 1984; Hu, et al. 1986). (2) The clinical classification of Chinese acquired dyslexia. According to whether dyslexia is accompanied by dysgraphia, a classification was made to divide Chinese acquired dyslexia into the dyslexia with dysgraphia and pure dyslexia without dysgraphia. This is the same as one of the clinical classifications of acquired dyslexia in alphabetic languages (Wang, et al. 1959; Tang, 1978; Wang, et al. 1981; Li, et al. 1984; Hu, et al. 1986). (3) The relationship between speaking ability and reading capacity. A study has found

that speaking ability has a supporting effect on reading capacity (Hu, et al. 1983). In this study, a patient who was diagnosed as an alexia with agraphia but without aphasia was carefully examined. It was found that when he was reading a text he quite often used his speaking ability (repeatedly speaking to himself according to the reading material) to facilitate his understanding of the content and sometimes he was successful. (4) The levels of reading impairments. According the levels of reading disorders are manifested, i. e. whether they are in the level of words or in the level of sentences, a differentiation has been made to distinguish word level dyslexia and sentence level dyslexia (Hu, et al. 1986).

1.6.3. CHINESE DEVELOPMENTAL DYSLEXIA STUDIES

While reading disability in children has become a common public concern in Western countries, it has attracted only little academic attention in China where it has not been considered a serious problem. Some studies in this field have been conducted outside China. However, the few studies which are concerned with the problem of reading disability in Chinese language have produced surprising results.

Kline and Lee (1972) made a transcultural study on reading disability, comparing the reading English with the reading Chinese. In their study, 277 Canadian Chinese children who were simultaneously learning English and Chinese were investigated on the achievement in reading either languages. The results showed a lower incidence of reading difficulty in Chinese than in the English language.

Kuo (1978) conducted a study on reading disability in Taiwan. He found Chinese children seldom had reading disabilities. Many primary school teachers in Taiwan were unaware of the existence of such a learning problem. When the characteristics of reading disabilities were explained to them, they remarked that only a very limited number of their students fell into such a category.

Woo and Hoosain (1984) carried out a study on the visual and auditory function of Chinese dyslexic pupils. The results showed that dyslexic pupils made more visual-distractor errors in character recognition, and thus indicating the importance of visual processing in the reading of Chinese characters.

Rozin, Poritsky and Sotsky (1971) did an experiment teaching dyslexic pupils. In their study, several American developmental dyslexic pupils in reading English were taught to read English material represented in Chinese characters. The results showed that although these children had a serious reading disability for English, they were found to be successful in reading Chinese characters with which English words had been associated.

1.6.4. SUMMARY OF STUDIES OF READING CHINESE CHARACTERS

From the above review, we can see: In the field of experimental study on normal subjects' reading processes, two aspects have been mainly explored. One is phonological recoding, the other is lateralization. However, the results are more controversial than consistent. Some studies were in favour of a direct access for reading Chinese character, while others indicated a phonological recoding in reading characters. Since many studies

on this aspect are not directly but indirectly linked with reading the character (such as memory experiments and Stroop experiments), a further study on this aspect which more directly linked with the process of reading the character is needed. As for lateralization the situation is more complex. Some support the advantage of left hemisphere, while some others support the advantage of right hemisphere in reading the character. It is also noted that there is no research focusing on the phonological aspect in the lateralization of reading Chinese characters. Thus a further study in this lateralization field is needed particularly with respect to the phonological aspect, and such study will provide more information on the routes used for reading Chinese characters. In the field of studying acquired dyslexia, the neuroanatomical classification has been made and the positions of the lesions have been determined. Chinese acquired dyslexia have been revealed to be caused by some similar neuroanatomical pathology to that of alphabetic acquired dyslexia. In addition, speaking ability had been revealed to have a supporting effect on the ability of reading in one study. Moreover, the level of reading disability was examined which lead to a differentiation of word level dyslexia and sentence level dyslexia. However, there is no research on the types of acquired dyslexia in relation to psycholinguistic functions. No research has been directed to the cognitive model of reading Chinese characters. Thus a further study in this direction is badly needed. In developmental dyslexia field, research has revealed some script effects on the developmental dyslexia.

Developmental dyslexia seems not to be a serious problem in Chinese children. Moreover, an important aspect of reading Chinese characters, i.e. visual processing, has also been examined through experiment with Chinese developmental dyslexia. These have thrown light on the understanding of reading process through research on developmental dyslexia of Chinese children. But there is vital shortage: no survey on developmental dyslexia has been carried out on in Mainland China, and this need to be carried out in the first place.

On the whole, in Chinese studies, there is an obvious shortage of research towards the three key issues in reading. So far, there is no answer for the question of whether reading Chinese characters is a single route or a multi-route, and the attempts are very limited and insufficient. These suggest that we badly need a further study on reading Chinese characters which is directed to the main issues of reading.

1.7. QUESTIONS AND OBJECTIVES OF THIS STUDY

(1) Key questions in reading Chinese characters

As said before, this study is aimed to provide information for the universal and language specific properties of reading by studying the processes of reading Chinese characters. To this central objective, there are three key questions: (a) Is the transcoding from the character to its meaning mediated by more than one route? (b) Is the transcoding from the character to its pronunciation mediated by more than one route? (c) Are the routes involved in the above procedure independent?

As we have seen from the above literature review, studies on alphabetic languages have presented much information about the three similar key questions in reading alphabetic words. There have been many experiments with normal adults reading processes, in acquired dyslexia, and in developmental dyslexia. What is remarkable is that several different types of acquired dyslexia, in the light of cognitive function, have been discovered by cognitive neuropsychology. Consequently, theoretical considerations have been developed in which the multi-route model has been proved to be successful. These have set up a cognitive neuropsychological research ground for furthering our understanding of reading processes. On this ground, the trend in reading studies of alphabetic words is dominated by multi-route models which suggest either transcoding from word to its meaning or transcoding from word to its pronunciation is achieved on the basis of several procedures, and the routes involved are independent.

However, considering the very fact that there are different scripts used as written languages in the world and there are obvious differences between alphabetic words and non-alphabetic scripts, especially Chinese characters, it would be important to see if the multi-route model is also suitable for non-alphabetic scripts. Unfortunately, as we have seen from the literature review, such studies have not been fully extended so far. Nevertheless, the studies of reading Japanese, and the studies of reading different forms of numbers in alphabetic languages have revealed a very important factor in reading processes, that is the

script effect. This script effect indicates the existence of some script specific features of reading. To what extent the script differences affecting reading process is, therefore, the key point in this issue. The criterion used in classifying Japanese deep and surface dyslexia could be an exaggeration of this script difference although it may be suitable for clarifying the patients using the two Japanese scripts, Kanji and Kana. Because of the similarity between Japanese Kanji and Chinese characters, the script effect found in reading Japanese language suggests that studying Chinese characters will be rewarding. Moreover, as we have mentioned before, Chinese characters have some important differences from their counterparts in Japanese Kanji, which should be taken into consideration when examining our reading processes. This sheds a promising light for deepening our reading studies. The questions as to whether the multi-route model is applicable to reading Chinese, and whether there are any characteristics in this aspect, will certainly contribute much to the establishing the universality and language specific features of reading.

A core issue, phonological recoding, will occupy an important position in this study. It is quite obvious, for a script which has no spelling-to-sound correspondence, the role the phonological recoding plays will certainly provide vital evidence for establishing the nature of reading processes. Moreover, an important aspect in reading Chinese characters, lateralization, is also needed to further investigate in considering the relationship between reading models and hemisphere functions particularly with

respect to Chinese characters.

In order to achieve the above aims. First of all, a deep analysis of Chinese characters is needed.

(2) The need for a deep analysis of Chinese characters.

It is quite obvious, all of the above concerns can only be satisfactorily carried out when we have a deep understanding of the characteristics of Chinese characters. To see whether there are any special types of acquired dyslexia for Chinese characters, we first of all need to find out what the characteristics of Chinese characters are. To see how people deal with the visual form of the script we first of all need to know what the properties of the form of the script are; to see how the phonological route functions in reading Chinese characters we need first of all to examine the phonological structure of the script. To see what Chinese developmental dyslexia is like, we need, first of all, to find the features of the script children have to read. The analysis of Chinese characters should be the basis of the study of reading Chinese characters. Without such analysis the study of reading Chinese characters will have difficulty avoiding superficiality.

(3) Three approaches in this study

In this research on reading Chinese characters, three approaches are used: (a) experiments on reading processes in normal subjects. (b) studies of acquired dyslexia. (c) study of developmental dyslexia.

The experimental study on normal subjects can give us information on reading Chinese characters under normal and control

conditions. Clinical research can give us a view on reading Chinese characters by abnormal subjects. Some aspects of reading Chinese characters can be better examined in normal experiments, such as phonological recoding and lateralization. Some aspects of reading Chinese characters can be better investigated by clinical research on acquired dyslexia, such as the damaged reading routes. Therefore, in order to get a more complete picture of the process of reading Chinese characters, the normal experiments and clinical studies should be combined together. The critical aspects of reading Chinese characters should be investigated in both experimental field and clinical fields.

The developmental aspect in reading is a necessity for understanding its nature, and there is a shortage for studies of developmental dyslexia especially in Mainland China. Thus, to assist the experimental and clinical research on reading Chinese characters, I need to do a study on Chinese developmental dyslexia as well. As we have seen there has been no developmental dyslexia survey in Mainland China so far, therefore such a survey is very much needed.

(4) Outline of this study

Bearing in mind the above concerns, a systematic research project has been carried out in the following relevant respects and the results are represented in the corresponding chapters:

(a) The analysis of Chinese characters

Chapter Two represents the study in this respect. This analysis will constitute the linguistic basis of research on

reading Chinese characters. It presents critical information on (a) the configurational properties of Chinese characters, (b) the phonological properties of Chinese characters. This study will examine the structure of Chinese characters, the types of construction and the special features of the configuration of Chinese characters. It will offer some statistical analysis of the phonological features of Chinese characters, such as the reliability of sound representation by the components of Chinese characters, and thus set up a critical database of the characteristics of Chinese characters for further study of the reading process.

(b) Experimental studies on reading Chinese characters

Chapter Three will present information on the three key issues of reading Chinese characters from experimental field. In this experimental field, I will try to find (1) If there is evidence for using multi-routes in normal subjects' reading procedure. To this end, I will examine whether the types of reading symptoms which are sensitive for multi-route model can be found in normal subjects' reading process. (2) If there is further evidence for phonological recoding in reading Chinese characters, and this is very important for the existence of phonological route in reading Chinese characters. (3) If there is evidence for the characteristic of reading Chinese characters due to the features of the configuration of Chinese characters. (4) If there is further evidence for lateralization of reading Chinese characters especially in relation to phonology.

(c) Studies on Chinese acquired dyslexia

Chapter Four will present vital information concerning the routes involved in reading Chinese characters from clinical case studies. The methods used for this study will be oriented to reveal: (a) whether some special relationships between the form, sound and meaning of the characters exist in dyslexic patients; (b) whether there are some Chinese counterparts of acquired dyslexia of alphabetic languages, such as: deep dyslexia and surface dyslexia; (c) whether there are some special types of acquired dyslexia in reading Chinese characters. Since this will be the first study on this aspect of Chinese acquired dyslexia, its database will therefore be very important.

(d) The study on Chinese developmental dyslexia.

Chapter Five will be the first attempt to explore Chinese developmental dyslexia on a large scale in Mainland China, and it will set up another database for furthering our understanding of reading Chinese characters.

(e) A theoretical analysis of reading Chinese characters.

Chapter Six represents the study in this respect. This analysis will be made on the basis of all above studies. It will give a theoretical discussion for the routes used in reading Chinese characters. It will examine whether a multiple route model is applicable for reading Chinese characters, and thus discuss the universality of the multi-route model.

CHAPTER 2

ANALYSIS OF CHINESE CHARACTERS

Since the characteristics of the neuropsychological process in reading Chinese characters are probably closely related to the linguistic features of the characters, the first step in studying this process is to do an analysis of Chinese characters.

There are two aspects of the features of Chinese characters in relation to reading: one is the complex visual structure of the character; the other is the special phonological organization of the character. Therefore the analysis of Chinese characters will focus on these two aspects. But first of all, as the background for this analysis, we need a general look at the Chinese language and Chinese characters.

2.1. THE CHINESE LANGUAGE AND CHINESE CHARACTERS

2.1.1. LANGUAGES USED IN CHINA

There are currently many languages used by Chinese people in China due to the fact that China is a unified multi-national country. On the whole, they can be divided into two categories: one is Hanyu which is used by the Han nationality, the others are minority languages which are used by Chinese minorities. The former encompasses about 90 percent of all Chinese people, the latter about 10 percent (Huang, 1985). Usually, the term "Chinese language" means Hanyu.

2.1.2. HANYU AND ITS SOUND SYSTEM

Hanyu is actually a group of languages used by Han

nationality. There are obvious differences amongst these languages in their phonological features. The differences are so big that a conversation between any two of them is usually impossible. Based on these, Hanyu is divided into seven main dialects (Zhou zhenhe and You rujie, 1986; Yuan jiahua et al, 1960; Zhan buohui, 1981; Xing gongwan, 1982). They are: (1) The Northern dialect. The number of people using this dialect in Han population is over 70 % in Mainland China. It is the basis of standard Chinese which is called Putonghua (it is a convention that Mandarin has been used to refer to Putonghua outside China). (2) Wu dialect. The percentage is 8 %. (3) Gan dialect. The percentage is 2 %. (4) Kejia dialect. The percentage is 4 %. (5) Xiang dialect. The percentage is 5 %. (6) Min dialect. The percentage is 4 %. (7) Yue dialect (another name for this dialect is Cantonese). The percentage is 5%.

Among overseas Chinese in Hongkong, Macao and other areas, Min, Kejia and Yue dialects are used.

In Taiwan, the Northern dialect is commonly used with Min and Kejia dialects distributed over many areas.

Hanyu is a tone language. Putonghua, as the standard form of it, has four tones. Different dialects vary greatly in the number of tones which they possess: some have seven, eight or more tones (c.f. Cantonese has nine tones), very few have only three tones.

Hanyu belongs to Sino-tibetan language family. It is an "isolating" language in which grammar works exclusively by stringing separate words together rather than by modifying the

pronunciation of words (Sampson, 1985). As such, Hanyu is more easily represented by characters -- the visually separated written form representing morphemes/words -- than inflecting language, like Japanese in which a development of Hiragana is needed to indicate inflexions. Hanyu has a monosyllabic system in which whole syllables or combinations of syllables correspond to morphemes/words. For example, the word for mountain is written in Chinese as 山 which is pronounced [shān] -- a whole syllable devoted to this character. In Hanyu syllables are clearly distinguished from one another phonologically, and this principle matches the rule by which characters are clearly demarcated from one another visually.

2.1.3. CHINESE CHARACTERS ARE THE UNIFIED WRITTEN FORM OF HANYU

Although Hanyu can be divided into seven dialects in which phonological differences make the conversation between different dialects very difficult, it is remarkable that Hanyu has only one written form, and that is the Chinese character, Hanzi. As the unified script for Hanyu, Chinese characters are used in different dialects, so that even though two different dialect speakers could not understand each other through conversation, they nevertheless could turn to writing for help, and by this way communication will certainly be successful.

Due to the contradiction between Hanyu's one written system and Hanyu's many phonological systems, a character can have very different pronunciations in different dialects. Such as: 人 is a

character, in Mandarin, it is pronounced [rén]; in Wu dialect, pronounced [nín]; in Yue, 'jén'; etc. But no matter how different the pronunciations for the character 人 are, the meaning of 人 in different dialects is the same, it means person.

Chinese characters are independent of variant phonological systems of Hanyu (unlike alphabetic scripts that reflect historical sound changes, at least in part), and thus they make Hanyu unified. They not only cover the distances among dialects in the geographical aspect, but also bridge the gap between the past and the present in the historical aspect of Hanyu since they are consistent over a long history. In a word, Chinese characters are like a unifier which makes Hanyu a unity geographically and historically.

2.1.4. THE ORIGIN AND DEVELOPMENT OF CHINESE CHARACTERS

The Chinese character is the only written form used in the world which has not changed its logographic nature. It is hard to understand this logographic system without a knowledge of the historical development of the characters, unlike alphabetic languages, where you only need to know what sounds are represented by the letters (some exceptions in English, where knowledge of the development of both spelling and the language helps with modern spelling, at least a little).





Although no strong evidence so far has been found to demonstrate the actual start of Chinese characters, there is a common agreement that the first systematic written form which can be thought of as a mature script for Chinese was Jiaguwen. Jiaguwen

can be dated back to 3500 years ago. They were the written symbols of late Shang dynasty inscribed on tortoise shells and animal bones, so they were also called the Shell and Bone characters.





Starting from the Shell and Bone characters, Chinese characters have developed an evolutionary process in which their forms have been undergoing continuous change. This process has the following steps: The Shell and Bone characters (B.C. 1700 - 1400) -- The Bronze inscription characters (not clear) -- The Great Seal characters (B.C. 776 - 250) -- The Small Seal characters (B.C. 250 - A.D. 25) -- The Clerical characters (A.D. 25 - 220) -- The Regular characters (A.D. 380 - Present) (Tao, 1966).

To illustrate this evolution of Chinese characters, two examples are given here:

(i) The development of character for turtle 龟 [guī]:

 (Shell and Bone character) --  (the Great Seal character) --  (the Small Seal character) --  (the Clerical character) -- 龟 (the Regular character).

(ii) The development of character of horse 马 [mǎ]:

 (Shell and Bone character) --  (the Great Seal character) --  (the Small Seal character) --  (the Clerical character) -- 马 (the Regular character).

There were two revolutions which happened in this evolution process. One was the radical change from the Great Seal characters to the Small Seal characters. This changed a system of constructing characters which resembled objects into a system of constructing characters which depicted objects by organizing

rectangle structures. The other was the radical change from the Small Seal characters to the Clerical characters. This changed the curved strokes which were necessary to resemble the real objects to points and straight lines, and greatly simplified the structures of characters. The radical change from the Small Seal character to the Clerical character is regarded as the most important event in the evolution of Chinese characters. This event radically changed the pictorial nature of Chinese characters, and made them no longer resemble vividly the real objects. Thus the symbolic point and line patterns for Chinese characters were finally set up. At the present time, most of the Chinese characters still keep the patterns which were set up in the Clerical characters.

2.1.5. THE CURRENT REFORM OF HANYU AND THE SIMPLIFICATION OF CHINESE CHARACTERS

To meet the needs of the social-economic development of the country, the Chinese government has carried out a reform of Hanyu since the 1950s. This reform is aimed at overcoming three serious problems in using Hanyu: (1) the complexity of the structures of Chinese characters; (2) the existence of different pronunciation systems for Hanyu; (3) the lack of a phonological system in Hanyu. Consequently, the reform of Hanyu is divided into three relevant tasks: (1) Simplifying Chinese characters. (2) Standardizing spoken language, i.e. spreading a nationally common speech, Putonghua. (3) Creating and popularizing a Chinese phonetic alphabet, Pinyin. The task of simplifying Chinese characters is so important that people sometimes regard the reform of Hanyu as the

reform of the Chinese written system.

The complexity of the structures of Chinese characters gives rise to many difficulties in learning them and using them. To solve this problem, a strategy has been used which is to simplify their structures by reducing their strokes. In 1956, a plan of simplifying Chinese characters was issued by the State Council of the People's Republic of China. This plan consisted of 515 simplified Chinese characters and 54 simplified Chinese radicals. Since many Chinese characters are constructed by radicals, these simplified radicals have therefore produced a great effect of simplification.

At the present time, the structures of the commonly used Chinese characters have been greatly simplified and used in Mainland China, but most overseas Chinese still use old characters.

2.1.6. THE INFLUENCE OF CHINESE CHARACTERS OVER OTHER LANGUAGES IN EAST ASIA

Chinese characters form the basis of writing systems for languages in East Asia, notably Japanese and Korean.

JAPANESE. Historically, Japan did not adopt Chinese characters directly from China, but from Korea indirectly. In A.D. 285, some Korean scholars introduced Chinese characters to Japan when they visited there. Since then, Chinese characters had been popularized and used there purely as the written script for Japanese until around the eighth century when the other kind of script, Kana, was created in Japan (Wellish, 1978; Guang Hua, 1989). Japanese language is very different from Chinese. It does

not belong to Sino-Tibetan family but is probably affiliated to Altaic languages like Korean (Miller, 1971). It is not an "isolating" language but an "inflexional" one. These differences made the adoption of Chinese script for writing Japanese difficult (Sampson, 1985) and eventually Kana which is a phonologically based script system has been developed to meet the need of an inflexional language. As a result, Japanese becomes a complex biscriptal system (kanji and kana, kanji is the term used in Japanese for Chinese characters). Kana was created in order to transliterate foreign words that they borrowed, especially proper names, and also to represent grammatical forms, which are expressed in very different ways in Chinese and Japanese. Kana has two types, one is Katakana, the other Hiragana which is for grammatical formatives. Kanji is usually used when writing nouns, verbs and adjectives. Although the meaning of a kanji is often similar to its counterpart in China, the way of pronouncing the character is nevertheless very different from Chinese. There is a quite complicated sound system used for pronouncing kanji. Unlike Chinese characters used in China which usually have one pronunciation (with some exceptions), Kanji characters usually have two pronunciations: an On-reading (based on Chinese) and a Japanese Kun-reading but sometimes several On-readings. A reader has to decide which reading should be employed against the background where the particular character is set. At the present time, Japanese still use such a complex biscriptal system in their writing.

KOREAN. It is generally thought that Chinese characters came

to Korea in the Han dynasty (206 B.C.-220 A.D) (Lin donxi, 1983). Although as a spoken language, Korean is very different from Chinese since it belongs to an entirely separate language-family, the Altaic family, while Chinese belongs to Sino-tibetan family, Korean borrowed Chinese characters on a massive scale. Chinese characters are so deeply rooted in the Korean language that until 20th century the normal medium of written communication in Korean was in Chinese script and only after second world war has the native written script, Hangul, been used generally. The Hangul script is traditionally regarded as created by King Sejong (reigned 1418-1450). This wonderful script is strictly phonetic, with phonetic features systematically represented (Sampson, 1985). Nowadays, in South Korea, language is still written in a mixed script in which Chinese characters are used for Sino-Korean words and Hangul for native forms. However, a trend toward using Hangul purely has been underway though old generation still prefer to use the mixed script; but in North Korea, writing is exclusively in Hangul after the script reform of 1948 (Jiang shanguo, 1987).

2.1.7. THE PROBLEM OF CHINESE ILLITERACY AND LEARNING TO READ CHINESE CHARACTERS

According to the survey of population of China in 1987, the proportion of illiterates is 20.6 % (Guang Ming Daily 1987). Illiteracy is a big problem faced by China. To a great extent, this problem relates to the difficulty of learning Chinese characters.

Generally speaking, learning to read Chinese in school is

divided into four stages: (1) The stage of learning Pinyin. In order to learn how to pronounce Chinese characters in a standard way, i.e. Putonghua, Chinese readers need a way of representing the sounds of the language to facilitate their learning process. According to current elementary school education programme, Pinyin should be taught in the very beginning in the procedure of learning to read Chinese characters. The period of learning Pinyin is the first two years in the school. (2) The stage of learning the basic structure of Chinese characters. Paralleling the process of learning Pinyin, pupils are also required to learn the basic structure of Chinese characters. Teachers first introduce them with the strokes which make up all Chinese characters, then the radicals which are made from the strokes, and finally the characters which are made from the strokes and radicals. This process of learning the basic structure of Chinese characters is required to be started also in the first year of elementary school and continue through the first half of the period of elementary school education according to the current elementary school education programme. This learning process is accompanied by writing practice in which a traditional brush writing is employed to strengthen pupils ability to write Chinese characters in the correct way and with strokes in the standard order. (3) The stage of synthesising scripts' configurations, sounds, and meanings. By the time pupils have learnt Pinyin, the basic structure of Chinese characters and the ways to write characters, they then advance into the stage of synthesising scripts' configurations, sounds, and

meanings. This stage happens in the late period of the first year of elementary school. At this stage, pupils are required to pronounce the characters being taught, in order to obtain a feedback effect for consolidating the connection between the characters' sound and their configuration. When teaching pupils a character, the teacher writes the character on the blackboard, then provides Pinyin for the character, and explains the meaning of the character as concretely as possible. In these circumstances, pupils are required to connect the configuration and the meaning of the character with its sound by reading it aloud. Meanwhile, with the help of writing practice they have to remember the structure of the character. This process is repeated over and over again whenever a new character is taught. (4) The stage of learning compound words. Since lots of Chinese words are not single-graphs, the stage of learning Chinese compound words - the combinations of characters is started soon after pupils have set up the basis of knowing several single-graphs. This also happens in the late period of the first year of elementary school.



As we can see from the above description of the learning procedure for reading Chinese characters, all the four stages are connected with each other in parallel and serial ways; they are started earlier in elementary school and are continuously carried out throughout the entire elementary education. In this way, pupils accumulate the characters they have learnt and by the end of elementary school they should have mastered about 3000 Chinese characters.

2.2. THE STRUCTURE OF CHINESE CHARACTERS

In the structure of Chinese characters, two classifications are made: One is to divide them into four categories in the light of the ways they were created -- there are pictographic characters, indicative characters, associative characters and pictophonetic characters. The other is to divide them into two categories in the light of structural complexity -- there are single-graphs, and combination-forms.


2.2.1. FOUR TYPES OF CHINESE CHARACTERS

(A) PICTOGRAPHIC CHARACTERS

Pictographic characters are constructed by drawing the objects with a minimum number of strokes. These picture-like characters originally sketched the basic forms of the objects as seen from above or from behind or from the side. Thus, the character for bird was drawn in the form of a bird, , is now written 鸟; and the character for fish was in the form of a fish, , and is now written 鱼, etc. At present, most pictographic characters no longer realistically represent objects, and it is difficult to perceive the vivid shapes of the original objects from the majority of modern pictographic characters; nevertheless, from their changed forms some clues can still be found taking us back to their ancient ancestors. Here are some examples of pictographic characters:

日, originally as , meaning sun, pronounced [rì].

月, originally as , meaning moon, pronounced [yuè].

牛, originally as , meaning cow, pronounced [niú].

(B) INDICATIVE CHARACTERS

Indicative characters are constructed to represent some abstract meanings which can not be made by sketching object forms. Characters of this kind were usually made by adding some strokes to some pictographic characters which already existed. For instance,

木 is a pictographic character, meaning tree, pronounced [mù], by putting a stroke " - " on its vertical stroke, a indicative character 本 is formed, which means base, pronounced [běn]. As we can see, the bottom of the tree is the root, and the root is the base of the tree, therefore the abstract meaning of base is represented. Some examples of indicative characters are as follows: 刃 , means blade, pronounced [rèn], while 刀 means knife, pronounced [dāo], putting a stroke " \ " to it, forming 刃 , indicates the sharp side of knife, therefore means blade. 中 , means middle, pronounced [zhōng]. It was possibly constructed originally by letting an arrow 𠂔 pierce its target 口 in the middle, 𠂔 .

(C) ASSOCIATIVE CHARACTERS

Associative characters are constructed by combining two or more existing characters or patterns of combinations of strokes. The meaning of an associative character can be derived from associating its individual components' or characters' meanings. For example, 尘 is an associative character, means dust, pronounced [chén]. It consists of two components, 小 and 土 , both components have their own meanings. They themselves are characters too. 小 means little, pronounced [xiǎo], which is a

pictographic character. 土 means earth, pronounced [tǔ], which is a pictographic character too. The meaning of 尘 can be derived from logically associating 小 and 土 together. 从 is an associative character, pronounced [cóng]. It consists of two single-graphs which are the same 人, they are pictographic characters and pronounced [rén]. Each means a person, or human being, thus construct an associative meaning of 从, "to follow". The logic of this association is that two men one is after the other, thus, following. It is clear that associative characters have a logical, associative structure in which the components are equally operative in symbolizing whole meanings. These kind of characters rely for their meanings on the interaction or association of their composite elements which are at least two, sometimes three, sometimes even more.

(D) PICTOPHONETIC CHARACTERS

Pictophonetic characters are constructed by two components, a meaning component, and a phonetic component. These two components come from the existing pictographic characters, indicative characters and the basic fixed patterns of combinations of strokes. It is the same as in the case of associative characters that the components of the characters are usually called radicals, the two components of pictophonetic characters, i.e. the meaning component and the phonetic component, are usually called the meaning radical and phonetic radical respectively; however, for more convenience, I would like adopt Sampson's (1985) terms, the signific (meaning radical) and the phonetic (phonetic radical), for

them.

The two components of pictophonetic characters keep their function separate. The phonetic has the function to do with the sound. It shows, though not always reliably or accurately, how the character is spoken. The signific has the function to do with the meaning. A signific does not represent the precise meaning a character stands for; instead, it indicates the class or range of meaning that a character can fall into: such as water, 氵, fire, 火, hand, 扌, metal, 钅. etc. An example of pictophonetic character is 捡, "to pick up". In this, the right part 佺 represents pronunciation of the whole character - jiǎn. The left part signifies the meaning of the character - something to do with hand. With alteration of the signific, the character can become 睑, "eyelid" (the right part indicating the same pronunciation, and the left signifying it is something to do with the eye); or 剑, "sword" (in this case, the left indicating the sound, and the right signifying the character stands for a kind of sharp thing). The position of the phonetic and signific in pictophonetic characters is variable. They can be on the left, or on the right, or on the top, or on the bottom, etc. However, in most cases, phonetics are located on the right, while significs are on the left.

2.2.2. TWO SORTS OF CONSTRUCTIONS

(A) SINGLE-GRAPHS

Single-graphs refer to a type of character whose structures are stable and comparatively simple. The organization of strokes

or the ways the strokes are combined in single-graphs make it impossible to separate the characters into smaller meaningful units of characters. For example, 刀 is a single character, meaning knife, pronounced [dāo]. It can not be separated into smaller meaningful units. 口 is a single character, meaning mouth, pronounced [kǒu], it also can not be separated into any more smaller meaningful units. Some more examples: 子, meaning son, pronounced [zǐ]; 女, meaning woman, pronounced [nǚ]; 心, meaning heart, pronounced [xīn]; 山, meaning mountain, pronounced [shān]; 水, meaning water, pronounced [shuǐ], etc. All of these are single-graphs, they can not be further divided into smaller meaningful units of Chinese characters.

(B) COMBINATION-FORMS

Combination-forms refer to a type of Chinese characters which have a complex structure compared with that of single-graphs. This type of character differs from single-graphs in that it can be divided into smaller meaningful units, i.e. radicals. The radicals can be single-graphs themselves or fixed meaningful patterns of stroke combinations. This separability among the components of combination-forms is impossible in single-graphs. Being separable from each other, radicals therefore can be associated with each other in constructing different characters (combination-forms). The same radical can appear in different combination-forms. Different combination-forms are actually different combinations of radicals.

Associative characters and pictophonetic characters are

combination-forms. Through examining the construction of their components, the above characteristics of combination-forms, i.e. their components being able to be separated, and consequently being able to be associated with one another, can be revealed clearly. For example, 子小 is an associative character, meaning grandson, pronounced [sūn]. It can be further divided into two single-graphs, 子 and 小. 子 means son, pronounced [zǐ]. 小 means little, pronounced [xiǎo]. 子 and 小, again can be components of other associative characters, such as in 好, meaning good, pronounced [hǎo], 子 functions as a component; in 尘, meaning dusk, pronounced [chén], 小 functions as a component too. The separability and combining ability of 子 and 小 are manifested quite clearly.

In the case of pictophonetic characters, this characteristic of combination-forms is more obvious. The basic structure of pictophonetic characters is the organization of the two principal components: one is the signific which represents the character's meaning, the other is the phonetic which represents the character's sound. In many cases these two components are single-graphs themselves, although in some cases they are not single-graphs but evolved from single-graphs. They have a strong dissociative property and an associative property as well. Consequently, pictophonetic characters have developed into the main script type used in modern Chinese. For example, 口 is a single character, meaning mouth, pronounced [kǒu], but it is also a signific and can be a component of 呼 "exhale" [hū], 咕

"cluck" [gū], 吩 "instruct" [fēn], 响 "noise" [xiǎng], 咽 "pharynx" [yān], 唱 "sing" [chàng], etc. 中 as a phonetic, can be a component of 冲 "flush" [chōng], 肿 "swollen" [zhǒng], 钟 "bell" [zhōng], 种 "grow" [zhòng], 仲 "second" [zhòng], etc., while itself is a single-graphs, meaning middle, pronounced [zhong].

From the above analysis of combination-forms (associative and pictophonetic characters), we can see that radicals can be associated with each other to form different characters. However, there are restrictions for the position of some radicals in combination-forms. Such as "扌" always appear on the left on the combination-forms, while "丨" never appear on the left but always on the right. Obeying these rules, one can make up pseudo-characters by putting radicals together; disobeying these rules, non-characters will be produced.

2.3. THE PHONOLOGY OF CHINESE CHARACTERS

There are two questions in connection with the phonology of Chinese characters as far as reading is concerned. One is in what way Chinese characters represent their sounds and how reliable it is. The other is to what extent one can determine for sure a character's meaning through its sound.

2.3.1. SOUND REPRESENTATION AND ITS RELIABILITY AND ACCURACY

(1) How do Chinese characters represent their sounds?

In alphabetic languages, a word is constructed by letters, and different letters and groups of letters correspond to

different phonemes, the phonological units. Words can be spelled out on the basis of these phonological units, then the pronunciation of the word can be assembled from its components. Some spelling-to-sound rules exist in alphabetic languages which meet the needs of most pronunciation circumstances, while there are also exception words which do not follow these rules. Such as the word "pint"[paint]. Usually "i" in the similar situation should be pronounced [i] like "hint"[hint]. These constitute the content of accuracy of representing sound in alphabetic languages.

In Chinese language, as we have seen, there is no letter-based spelling-to-sound organization simply because characters are not constructed by letters denoting segments. Chinese characters cannot be divided into segments, as each character stands for a whole syllable. How then do Chinese characters represent their sounds?

In the analysis of the structures of Chinese characters, four types of character construction have been examined. We need here to look at them again from a phonological point of view in order to find the ways in which pronunciation is represented.

Pictographic characters. As we have seen, this type of character is made to represent the object that the character stands for. Since strokes have no correspondence in phonology, and the way pictographic character is organized has nothing to do with phonology, therefore, no phonological unit representative exists in this type of Chinese character. Pictographic characters are used to stand for some physical things, such as the sun, the moon,

mountain, water, etc.

Indicative characters. As we have seen this type of character is made to represent some abstract meanings, which can not be made by sketching an object's form. The structure of this type also belongs to the category of the single-graphs. Indicative characters are constructed by manipulating strokes in an abstract meaning indicating manner. Like pictographic characters, indicative characters do not contain any phonological indicators.

Associative characters. As we have seen, this type of character is constructed by combining two or more existing characters or patterns of combinations of strokes. Its meaning is represented by associating the individual meanings of its components, characters or fixed patterns of combination of strokes. Although associative characters are constructed by manipulating existing characters and patterns of strokes there is nothing to do with phonology in this construction and no phonological indicator exists in associative characters. Even though the components of associative characters can be sounded out, their pronunciations never bear a relationship to the pronunciation of the whole character.

Pictophonetic characters. Different from above three types, pictophonetic characters are the only type of Chinese character which does include a phonological indicator in its structure. As we have seen pictophonetic characters are constructed by manipulating two components made by existing characters and fixed patterns of the combination of strokes, the meaning component, the

signific, and a phonetic component, the phonetic. The phonetic works as a phonological representation indicating the pronunciation of the whole pictophonetic character. However, this indication of pronunciation is very different from the structure of spelling-to-sound in alphabetic languages, it is not constructed on the basis of individual components' pronunciation, rather it maps to sound on the basis of the phonological component to the whole pronunciation, it has nothing to do with spelling. The relationship between the phonetic and the pronunciation of the character is a holistic correspondence.

From the above analysis, we can see that Chinese characters do have a way of representing their pronunciations which is different from spelling-to-sound organization, but this sound indication is not involved in all types of Chinese characters. Even though only the pictophonetic character has phonological representation, it is still very important. The percentage of pictophonetic characters in all Chinese characters at present time is over 80 % (Huang, et al, 1985) and historically pictophonetic characters have become increasingly widespreded.

(2) How reliable and accurate is representation of sound by phonetics?

As we have seen from the above analysis, the sound can be represented through phonetics in pictophonetic characters. A following important question is how reliable and accurate this representation is. To solve this problem, we need to further examine the phonetics in their correspondence to the pronunciation

of pictophonetic characters. There are several types of phonetics in this correspondence. First, there are some phonetics which always represent characters' pronunciation correctly. For example, 匡 (pronounced [kuāng]), is such a phonetic. In all the cases where it appears, the pronunciation of the characters is always correctly represented by it: 匡 "the name of a place in Guangdong province, China" [kuāng], 诓 "deceive" [kuāng], 匡 "crash" [kuāng], 筐 "basket" [kuāng], 框 "frame" [kuāng], 眶 "the socket of the eye" [kuāng]. Second, there are some phonetics which sometimes represent characters' pronunciation correctly, sometimes not. For example, 皮 (pronounced [pí] in isolation) is such a phonetic. In some cases, the pronunciation of the characters is correctly represented: 披 "wrap around" [pí], 铍 "beryllium" [pí], 疲 "tired" [pí], 鲋 "bitterling" [pí]; while in other cases the pronunciations are different: 波 "wave" [bō], 玻 "glass" [bō], 被 "quilt" [bèi], 坡 "slope" [pō]. Finally, there are some phonetics which never represent characters' pronunciation for historical reasons. For example, 屈 (pronounced [qū] in isolation) is such a phonetic. e.g. 窟 "cave" [kù], 掘 "dig" [jué], 倔 "stubborn" [juè]. Based on these different correspondences between phonetics and pronunciations, we can calculate numerical values for the accuracy and reliability of representing sound through the phonetics. To do this, first of all, we need to figure out all the individual ratios of representing a sound through an individual phonetic, and thus to set up a database for further calculations. Then, on this basis,

we can further get: the average ratio of representing sound through phonetics; the ratio of complete representation of sound in all phonetics; the ratio of partial representation of sound in all phonetics; and the ratio of non-representation of sound in all phonetics.

I made such a statistical study based on a kind of Chinese dictionary-Han Zi Xingsheng Zi Hui (Zhong Hua Shu Jiu, 1979). This dictionary lists all the pictophonetic characters from Xin Hua Zi Dian (1971) which is the most commonly used dictionary by Chinese people in Mainland China. Xin Hua Zi Dian (1971) contains about 11100 characters including all commonly used pictophonetic characters. Han Zi Xingsheng Zi Hui picks out all the phonetics in these pictophonetic characters and put them in an alphabetic order according to their pronunciation in Pinyin.

1. The ratio of representing sound through individual phonetic is defined as:

$$RP = \frac{PN}{TC}$$

Here, RP stands for the ratio of representing sound through a phonetic.

PN stands for the number of characters whose pronunciation is correctly represented through that phonetic.

TC stands for the total number of characters which have that phonetic.

For example, 堂 is a phonetic. It is pronounced [táng]. There are 6 characters which contain this phonetic: 堂 "wade"

[táng], 鏜 "boring" [táng], 櫳 "door or window frame"
[táng], 螳 "mantis" [táng], 膺 "thorax" [táng], 瞠
"stare" [chēng]. So, TC = 6. Of them, five characters'
pronunciations are correctly represented by this phonetic, PN = 5.
Therefore RP = 0.83.

Having counted the number of characters whose pronunciation
is correctly represented through the phonetic, and the number of
characters which have that phonetic, then by using the formula
above, each RP was obtained respectively for all phonetics.

2. The average ratio of representing sound through phonetics
is defined as:

$$\text{ARP} = \frac{\text{SRP}}{\text{TP}}$$

Here, ARP stands for the average ratio of representing sound
through phonetics.

SRP stands for the sum of all the individual ratios of
representing sound through individual phonetic.

TP stands for the total number of phonetics in Chinese
characters.

If phonetics represented sounds with complete reliability,
then, SRP = TP, and ARP = 1. However, by summing each RP, for 1525
phonetics, SRP = 888.86;

Therefore,

$$\text{ARP} = \frac{888.86}{1525} = 0.58$$

* The standard deviation of this ARP distribution is 0.38.

Obviously, the ratio of representing sound through phonetics is not high. This indicates that the phonetics are not reliable indicators in general.

3. The ratio of complete representation of sound in all phonetics is defined as:

$$CRP = \frac{TCP}{TP}$$

Here, CRP stands for the ratio of complete representation of sound in all Chinese phonetics.

TCP stands for the total number of phonetics which correctly represent pronunciations for all of their characters (the characters employ these radicals as their components).

For example, 奐 [huàn] is a phonetic. It correctly represents the pronunciation for all the characters which use it as their phonetic: 渙 "vanish" [huàn], 煥 "shining" [huàn], 換 "exchange" [huàn], 喚 "call" [huàn], and 瘓 "paralysis" [huàn]. 乎 [hū] 肯 [kěn] and 匡 [kuāng] are other examples. TCP is the total number of this kind of phonetics.

TP has the same meaning as in the formula of $ARP = \frac{RP}{TP}$.

Through calculation, the total number of phonetics which correctly represent pronunciations for all of their characters was obtained.

TCP = 543

Therefore, the ratio of complete representation of sound in all phonetics was obtained.

$$\text{CRP} = \frac{543}{1525} = 0.36$$

This means that 36 percent of phonetics correctly represent the pronunciations of the pictophonetic characters in which they occur.

4. The ratio of partial representation of sound in all phonetics is defined as:

$$\text{PRP} = \frac{\text{TPP}}{\text{TP}}$$

Here, PRP stands for the ratio of partial representation of sound in all phonetics.

TPP stands for the total number of phonetics which correctly represent pronunciations for only some of their characters.

For example, 𦉳 [niè] is a phonetic. There are eight characters which contain it: 𦉳 "temple" [niè], 𦉳 "speak haltingly" [niè], 𦉳 "lighten" [niè], 𦉳 "tweezers" [niè], 𦉳 "the name of a place in Hubei province, China" [shē], 𦉳 "fear" [shè], 𦉳 "absorb" [shè], and 𦉳 "pleat" [zhè]. Four of them have their pronunciation correctly represented by 𦉳 [niè]. Therefore 𦉳 [niè] is a phonetic which partially represents the pronunciation of the characters. 午 [wǔ] and 免 [miǎn] are other examples.

The total number of phonetics which correctly represent pronunciations for some but not all of their characters was 733.

Therefore, the ratio of partial representation of sound in all phonetics was obtained.

$$\text{PRP} = \frac{733}{1525} = 0.48$$

This means 48 percent of phonetics partially represent the pronunciations of the pictophonetic characters.

5. The ratio of non-representation of sound in all phonetics is defined as:

$$\text{NRP} = \frac{\text{TNP}}{\text{TP}}$$

Here, NRP stands for the ratio of non-representation of sound in all phonetics.

TNP stands for the total number of phonetics which do not represent the pronunciations of the characters at all.

For example, 失 [shī] is a phonetic. There are ten characters which contain it: 跌 "fall" [diē], 迭 "alternate" [diē], 瓜失 "small melon" [diē], 铁 "iron" [tiě], 轶 "anecdote" [yì], 佚 "ease" [yì], 映 "beautiful" [yì], 佚 "indulge" [yì], 帙 "cloth slip-case for a book" [zhì], and 秩 "order" [zhì]. None of them have their pronunciations is the same as this phonetic. Therefore 失 [shī] is a phonetic which does not represent the pronunciations of pictophonetic characters. 庶 [shù] and 爰 [fā] are other examples.

The total number of phonetics which do not represent the pronunciation of any characters in which it occurred is 249.

Therefore, the ratio of non-representation of sound in all phonetics was obtained.

$$\text{NRP} = \frac{249}{1525} = 0.16$$

This means that 16 percent of phonetics do not represent the pronunciations of the pictophonetic characters at all.

Figure 2.1 is the distribution of RP's. Along the horizontal axis are sound representation ratios. Along the vertical axis is the number of phonetics (percentage in all of the phonetics) for each sound representation ratio.

Figure 2.1 Distribution of RP's

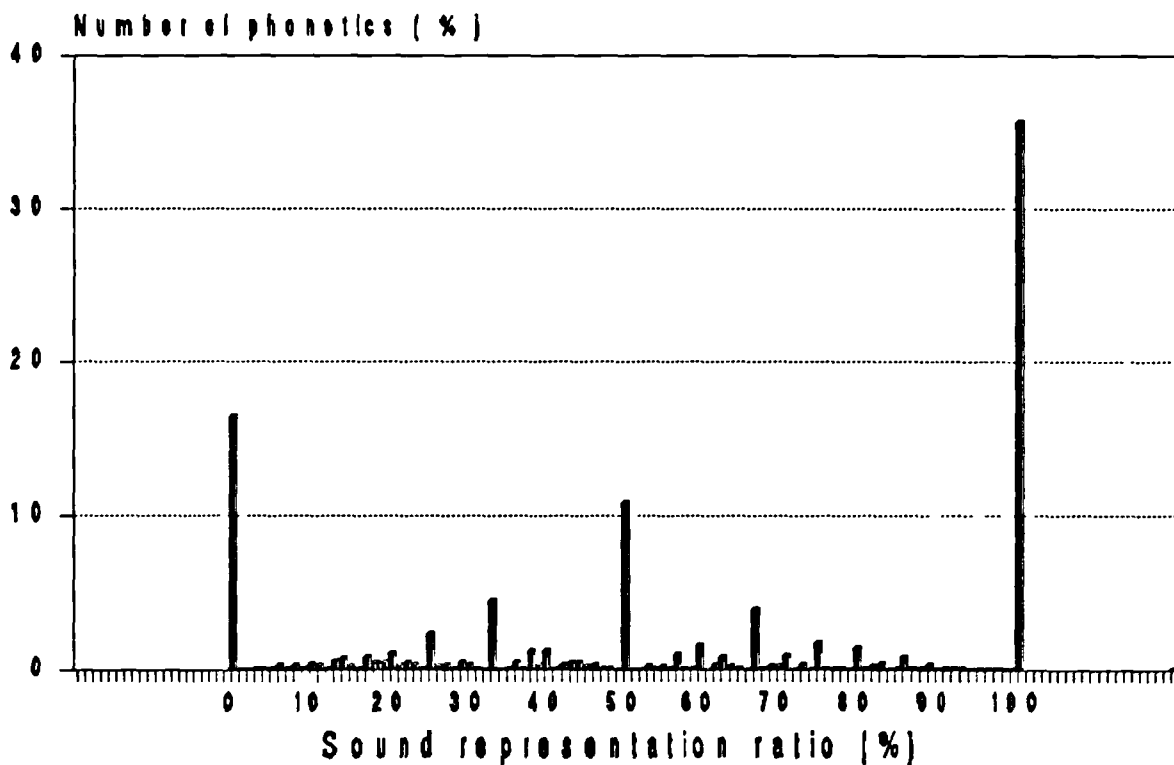
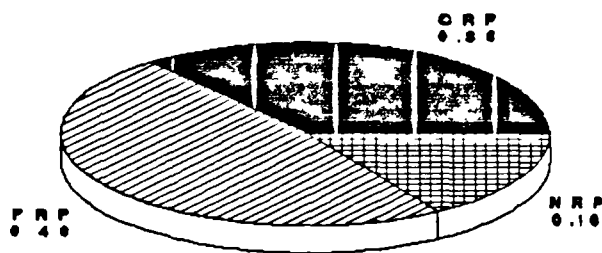


Figure 2.2 illustrated CRP, PRP and NRP in a proportional pie form.

Figure 2.2 Sound representation



2.3.2. MONOSYLLABIC SYSTEM AND THE RELIABILITY IN DETERMINING MEANING BY SOUND

In this section, we are going to examine to what extent one can determine for sure a character's meaning through its sound.

As we have mentioned before, Chinese characters are characterized by their monosyllable nature. One character is one monosyllable; and each monosyllable is a morpheme or a word. We have seen that the same syllable can have several meanings, represented by different characters. The further question therefore arises: how reliable a guide to meaning is pronunciation? This reduces, in part, to the question: how many monosyllabic morphemes are there in Chinese?

A syllable can be divided into two parts, the onset called in Chinese "Sheng-mu", and a rhyme, called "Yun-mu". For example, the syllable for character 中 is "zhōng" where "zh" is the onset, the "Sheng-mu", and "ong" is the rhyme, the "Yun-mu". "Sheng-mu" is constituted by either a consonant or the combinations of consonants. "Yun-mu" is constituted by a vowel, or combinations of vowels, or combinations of consonants and vowels.

In Mandarin, there are 21 "Sheng-mu"s, i.e. b, p, m, f, d, t, n, l, g, k, h, j, q, x, zh, ch, sh, r, z, c, and s; and there are 38 "Yun-mu"s, i.e. a, o, e, ê, i, u, ü, -i, î, ai, ei, ao, ou, ia, ie, ua, uo, ue, iao, iou, uai, uei, an, ian, uan, üan, en, in, uen, un, ang, iang, uang, eng, ing, ueng, ong, and iong.

As we know, the Chinese language is a tonal language, each syllable is assigned a tonal feature, and different tones of a syllable have completely different meanings, therefore, tones are the necessary components in forming Chinese monosyllables. There are 4 tones in Chinese pronunciation (Standard Chinese), i.e. -, /, v, and \.

If we calculate the number of the combinations of "Sheng-mu" and "Yun-mu" and tones, we come to the number of $21 * 38 * 4 = 3192$ combinations. However, not all of these combinations are existing syllables because there are some combination principles regulating the forming of the combinations of "Sheng-mu" and "Yun-mu". As a result, there are only 407 syllables in existence. Moreover, these 407 syllables can not combine freely with four tones. There are many restrictions hindering this combination. In an exhaustive

count, the actual number of existing monosyllables is only 1307.

Having examined the total number of meaningful monosyllables which are used to connect characters' form and their meaning, we now going further to solve the next question: How many of these monosyllables are reliable in the light of getting unique meaning from the character's form. This will give the reliability of determining meaning by sound.

In order to set some index to measure this reliability, we need first of all to examine how many kinds of connections exist from grapheme to meaning via sound in Chinese.

In the real sense, only five kinds of phonological conversions exist in Chinese which are for a) unique characters, b) homophones, c) synonyms, d) multi-sound characters (some Chinese characters have more than one pronunciation) and e) the characters with variations. The character which has more than one form but has only one pronunciation and the same meaning is *also a linguistic property* of Chinese script. There are two reasons for this *linguistic* phenomenon: one is that there is no strict requirement to stick the character's form to its pronunciation, consequently, freedom is left for developing more forms for one character; another factor is Chinese character's long evolutionary history and especially the recent reforming of its forms. A long history of development left many relics of Chinese characters, of which some still can be used in modern times. Simplifying Chinese characters in recent reforms has created many new simple forms for old character forms, and both forms are in

current use. For these connections, we need a further examination. Clearly, of all these four kinds of connections only unique characters can be the indicator for the reliability of determining meaning by sound.

Based on the above examination on the phonological conversion of different characters, we now can set up the index to measure the reliability of determining meaning by sound as follows:

$$RDS = \frac{P'}{P}$$

Here, RDS stands for the ratio of determining meaning by single characters' sound.

P' stands for the unique sound for unique character,

P stands for all meaningful monosyllables.

This ratio gives the percentage of unique phonological connections among characters' form, sound, and meaning in all the monosyllabic connections. In other words, the percentage of the cases in which meanings are determined straightforwardly (each meaning is represented by a separate characters). This index can be figured out by statistical calculation on Chinese characters based on Xin Hua Zi Dian (1979) which is a commonly used dictionary with vocabulary of about 11100 characters (mentioned before).

First I calculate the number of syllables which have only one character among 1307 meaningful syllables. The result is 255. Second, for these 255 characters I calculate how many of them have more than one pronunciation. The result is 102. Thus, the number of characters in the Chinese dictionary which are not homophones

which have unique sounds as well is: $255-102=153$. Third, for these 153 characters, I calculate how many of them have more than one form. The result is 39. Thus, the number of syllables in P in Chinese which have a unique character and a unique meaning is: $153-39=114$.

The value of P' is obtained by doing statistical calculation on the Chinese dictionary. $P' = 114$.

Therefore, the ratio of determining meaning by single characters' sound is obtained.

$$RDS = \frac{114}{1307} = 0.087$$

Obviously, this ratio is quite low.

The reason for this lies in the monosyllable feature of Chinese. Because of this feature, the number of meaningful sounds is greatly limited, but there are a great number of Chinese characters in use. Consequently, what happens? Many homophones appear. Homophones are the key factor which causes the uncertainty in the process from sound to meaning.

It is therefore worthwhile to set up some norms to quantitatively reveal the features of homophones.

Two norms can be set in this respect, one is the ratio of homophones, the other is the degree of homophones.

(a) The ratio of homophones

The ratio of homophones is defined as:

$$Hr = P(h) / P$$

here, Hr stands for the ratio of homophones,

P(h) stands for the syllables each of which has more than one character.

P stands for as defined before all meaningful syllables.

As for Chinese characters, we have seen from the above statistical studies:

the value of P is only 1307,

while the value of P(h) is: $1307 - 255 = 1052$,

therefore the homophone ratio of Chinese characters is:

$Hr = 1052 / 1307 = 0.805$

Very obviously, the ratio of homophones of Chinese characters is very high.

(b) The degree of homophones

The degree of homophones is a measure aiming to quantify the extent to which a homophonic syllable connects with characters. In other words, it is the degree to evaluate how many characters a homophonic syllable corresponds to, its value is just the number of the characters such a homophone syllable connects to, and it shows the power of the homophone syllable.

For example, [bu] is a homophone syllable, and the degree of [bu], i.e. $Hr(bu) = 13$, because there are thirteen characters all of which can be pronounced [bù]. They are: 不 "no", 呋 "name of local place", 钚 "plutonium", 布 "cloth", 怖 "fear", 簿 "book", 埔 "name of local place", 步 "step", 埔 "name of local place", 部 "part", 甬 "vase", 鄒 "basket", and 埠 "wharf".

The individual homophone degree gives the power of individual

homophonic syllable. To get a general picture of homophone degree of Chinese characters, we can define an average degree of homophones as the following:

$$\overline{Hd} = \sum_{i=1}^n \{Hd[p(h)i]\} / N$$

here, Hd stands for the average degree of homophones,

Hd[p(h)i] stands for the individual homophone degree,

$N = P(h)$, stands for the number of all homophones.

The statistics on this Hd is carried out on the current Chinese dictionary. For each homophonic syllable, i.e. p(h), I calculate how many characters connected to it, i.e. Hd of individual p(h). This sets up a database for homophone degrees of Chinese characters. After this, I use the above formula to get Hd. The result is:

$$Hd = 8259 / 1052 = 7.851.$$

This means more than seven Chinese characters share the same homophonic syllable on average.

2.4. CONCLUSION

For the purpose of assisting the research on neuropsychological process for reading Chinese characters, an analysis of Chinese characters was carried out on the configuration aspect and the phonological aspect respectively.

In the configuration aspect, Chinese characters are analysed in their different constructional forms. In the phonological aspect, first the ways of representing pronunciation in Chinese

characters has been analysed; second, the reliability and accuracy of representing sound by phonetics has been figured out; third, the monosyllabic system and the reliability of determining meaning by sound has been analysis and calculated.

Through this study, a general picture of Chinese characters has been revealed. In configuration, Chinese characters have a complex structure. There are four different types of characters (pictographic, indicative, associative and pictophonetic characters) which can be again categorised into two constructional forms (single-graphs and combination-forms). Moreover, there is a separability in these complex structures. In phonology, Chinese characters do have a way of representing their pronunciations. The extent to which this representation being made is: the proportion representing sound through phonetics (ARP) is 0.58; the proportion completely representing sound through phonetics (CRP) is 0.36; the proportion partially representing phonetics (PRP) is 0.48; and the proportion not representing sound by phonetics (NRP) is 0.16. Clearly, this representation can not be neglected, but the accuracy of this representation should also be taken into consideration when thinking about how reading is achieved. Moreover, there is a low certainty in determining meaning by sound. The ratio of determining meaning from a character's sound (RDS) is 0.087. This low certainty is especially due to the homophonic features of Chinese characters: the homophone ratio of Chinese characters (Hr) is 0.805; the average degree of Chinese homophones (Hd) is 7.851.

These features of Chinese characters are what we have to know

for carrying out further study on the process of reading Chinese characters because these features must, I presume, have some effects on determining the characteristics of the process of reading Chinese characters. The basic framework of the process of reading Chinese characters is based on these features.

Although Chinese characters, as a logographic system, are not constructed to symbolize their sounds in a spelling-to-sound manner, a way of representing their pronunciation, however, exists in one of their major types - pictophonetic characters - in which the phonetic takes the responsibility for representing sound. Taking this fact into consideration, I would predict the development of a phonological route via phonetics in reading pictophonetic characters, and therefore, the existence of a surface dyslexia in Chinese that relies exclusively on this route. This will show itself in "regularization" errors when reading the many characters whose phonetic clues not indicate the sound. Moreover, this reading route via phonetics can also be revealed through experimentation with normal subjects. However, considering the extent of sound representation by phonetics, I would predict that there will be a limitation to the use of phonetics, and such a limitation will be demonstrated in reading pictophonetic characters. Furthermore, considering the restriction of getting meaning from a single characters' sound (RDS is 0.0872) and the homophonic features of Chinese characters (Hr is 80.49%, Hd is 7.85), I would predict the general use of phonology in reading Chinese characters is limited and there should be some other ways

to compensate for such weakness. A possibility is that the access for meaning being mainly performed by non-phonological ways which are developed in reading practice and sometimes will be overused. If this is true, I will further reckon that homophone confusion may not affiliate with Chinese surface dyslexia if such dyslexia exists, but that semantic errors will be much easier to find in Chinese patients; and moreover, such errors will appear even in normal readers through experimentation.

CHAPTER 3

EXPERIMENTAL STUDIES ON READING CHINESE CHARACTERS

3.1. INTRODUCTION

The purpose of this research is to examine some important experimental issues in reading Chinese characters. I intend to see whether there are some common features shared by both reading Chinese characters and reading alphabetic words, and also whether there are some features which are determined by the special properties of Chinese characters. Three experimental aspects of the issue are addressed here: 1. automatic/obligatory phonological processing; 2. the lateralisation of reading Chinese scripts; 3. normal errors in speeded reading. Six experiments were conducted. Experiment 1 addresses the issue of the automatic/obligatory phonological processing in reading. Experiments 2 to 5 concern aspects of lateralisation: experiment 2, the lateralisation of visual recognition processes; experiment 3, the lateralisation of articulatory processes; experiment 4, lateralisation of phonological processing where articulation is not required; and experiment 5, lateralisation of semantic processing. Finally, experiment 6 focuses on the issue of normal errors in speeded reading.

3.2. AUTOMATIC/OBLIGATORY PHONOLOGICAL PROCESSING IN READING CHINESE CHARACTERS (EXPERIMENT ONE)

INTRODUCTION

The issue of the phonological recoding in reading is a very important aspect in understanding reading processes. From the

experimental studies on alphabetic languages, the following results have been obtained: phonological mediation may not be obligatory, but phonological processing does exist even where not required by the task, for example, pseudohomophone effect in lexical decision tasks. Where subjects are required to distinguish word and non-word letter strings, Rubenstein, Lewis, and Rubenstein (1971, found that non-words which sound like words (e.g., brane) received a slower "No" response than other pronounceable nonwords (e.g., slint). They attribute this effect to obligatory phonological recoding which interfere the lexical decision task for non-words.

However, existing research has not satisfactorily addressed the question of whether phonological recoding is obligatory or how it is achieved (see Chapter 1).

Chinese characters do not have a spelling-to-sound system. This puts them in a very different position from the alphabetic languages. Studies on the issue of phonological recoding in reading Chinese characters are controversial (Chapter 1). Some of them are actually not reading experiments. Moreover, no research has been carried out on the issue of whether there is phonological recoding in recognition of Chinese characters, and this issue is important because it will allow us to see whether phonological recoding is an automatic process or not.

DESIGN

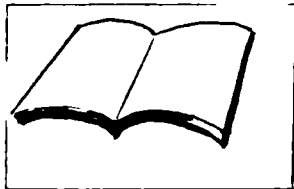
A Picture-character matching experiment was therefore designed to investigate the question of whether or not phonological recoding occurs in recognizing Chinese characters when

pronunciation is not required by the task.

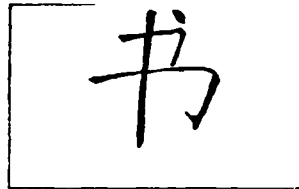
Three sorts of picture-character pairs were used in the experiment.

A (R)

(Real pair: picture and character are matched)



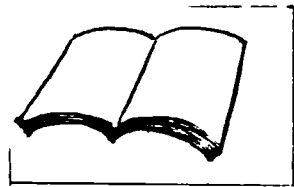
"book" [shū]



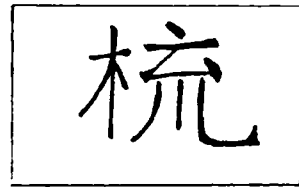
"book" [shū]

B (H)

(Homophone pair: picture's name and character are homophones)



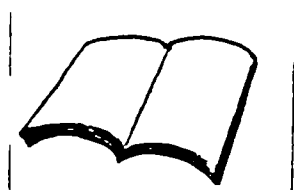
"book" [shū]



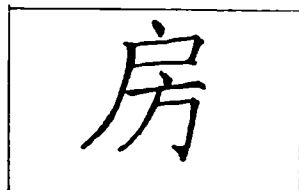
"comb" [shū]

C (N)

(Non-matched pair: picture and character have no relation)



"book" [shū]



"house" [fāng]

If there is no automatic phonological recoding in reading Chinese characters, then the matching decision time (MAT.RT) for "no" responses will be unaffected by the presence of a homophonic character, hence:

MAT.RT (B) = MAT.RT (C)

If there is automatic phonological recoding, then:

MAT.RT (C) < MAT.RT (B)

presumably,

MAT.RT (A) is shorter than the other two.

MAT.RT (A) < MAT.RT (B)

MAT.RT (A) < MAT.RT (C)

SUBJECTS

Twenty native Chinese Mandarin speakers. All of them came from the Peoples' Republic of China to study in London. Half of them were male, and half were female. Age range: 20s-40s. Handedness: all of them were right handed except one male who was ambidextrous. Education level: All had graduated from college or university.

STIMULI

Three kinds of stimulus were used in the experiment.

1. Picture-character (R)

Real pair (N = 22). Character names the picture.

2. Picture-character (H)

Homophone pair (N = 22). Picture's name and character are homophones.

3. Picture-character (N)

Non-matched pair (N = 22). Picture and character have no relation.

Stimuli were presented in a three field Tachistoscope. On each card was either drawn a picture or written a Chinese

character.

The size of each picture or character was approximately 34*34 mm.

All the pictures were clear and the objects depicted by the pictures were familiar to the subjects.

All the characters were common ones, i. e. the using frequencies of the characters were within the range of the 3000 most commonly used characters.

A same picture was combined with a same character, a homophone, and a different character to form a comparable group. There were 22 such groups. In each group, the frequencies of use of the homophone or the different character were quite similar (frequency differences between homophones and different characters within each group were small).

The numbers of strokes in the homophones and in the different characters were also similar (on average there were about 9 strokes in each character).

EQUIPMENT

1. Three field T-scope

Field 1: For the purpose of concentrating subjects' attention on the central point of the visual view scope, there was a central fixation point in the first field.

Field 2 presented the picture.

Field 3 presented the character.

2. Timer

A timer was connected with the third field, i. e. when a

character was presented to the subject, the timer was simultaneously triggered on to measure the reaction time. The timer started at the same time as the presentation of the character was started.

3. Reaction button

Subjects made a reaction by pressing the red or black buttons which were connected to the timer and would stop the timer.

Subjects used both hands to make a reaction, one was for "yes", one was for "no".

PROCEDURE

Subjects sat in front of the T-scope looking through the view window. He or she first saw the fixation point for 500 ms, then the picture for 200 ms, and finally the character for 150 ms.

Each subject was tested in 66 trials. The types of picture-character pair were randomly presented in the experiment. Subjects were asked to make a judgment as to whether the picture-character pairs presented were of the same meaning or not. For picture-character (s), the right answer was "yes"; For both picture-character (h) and picture-character (d), the right answer was "no". If the answer was positive (i.e. "yes") the subject should press the red button as the reaction: if the answer was negative (i.e. "no") the subject should press the black button as the reaction. Half of the subjects were asked to press the button using their right hand for a positive answer, and left hand for negative answer; the other half of the subjects were asked to perform in the reverse fashion.

RESULTS

Twenty subjects' reaction times were recorded and analyzed by using the BBC computer statistical package UNISTAT2.

Subjects' mean R.T.(s) were calculated from subjects' correct answers and presented in Table 1 in appendix A (1).

The design of this experiment was taken into consideration of the effects of sex and handedness. Subjects were divided into two groups by sex, i. e. half male and half female; and also two groups by manual reaction, i. e. half using right hand to react for correctly matched pairs while left hand was used to react for mis-matched pairs and half using left hand to react for correctly matched pairs while right hand was used to react for mis-matched pairs. Therefore, a three-way analysis of variance was conducted to analyze the effects of these different factors.

Table 3.1. Three-way ANOVA with 1 rptd. measure (RTcorrect)

DUE	DF	SSQ	MSQ	F
A	1	31.15	31.15	0.1
B	1	302.29	302.29	0.5
A*B	1	920.26	920.26	1.7
ERR	16	89.14.44	557.15	
C	2	319.55	159.77	12.5
A*C	2	42.58	21.29	1.7
B*C	2	211.58	105.79	8.3
A*B*C	2	60.78	30.39	2.4
ERR	32	409.94	12.81	
TOT	59	11212.57		

In Table 1, A was the factor of male vs female; B was the factor of right hand vs left hand; C was the factor of stimuli (tasks).

This multi-way analysis of variance showed that there was no difference in reaction time due to sex. There was no difference in reaction time due to the use of the hand alone. But there was a significant difference among performances for different stimuli, i. e. tasks difference was obvious; $F = 12.5$, $P < 0.01$. The interaction between sex and hand was not significant. The interaction between sex and stimuli was not significant. The interaction between hand and stimuli was significant; $F = 8.3$, $P < 0.01$.

As for this task differences, Table 3.2 gives us a general view.

Table 3.2. Mean R.T. (correct) etc. differences among different tasks (in centiseconds)

	P-C (R)	P-C (H)	P-C (D)
Mean R.T.	59.0636	66.3816	62.6631
Variance	149.3290	252.2620	162.1410
Standard Devia.	12.2200	15.8828	12.7335

T-tests showed that the differences between P - C (R) and P - C (H) was very significant, $t = 5.008$, $P < 0.001$ (two tailed); the differences between P - C (R) and P - C (N) was significant, $t = 4.265$, $P < 0.001$ (two tailed); and the differences between P - C (H) and P - C (N) was also significant, $t = 2.7161$, $P < 0.01$ (two tailed). Thus $MAT.RT(A) < MAT.RT(C) < MAT.RT(H)$ was confirmed.

DISCUSSION

From the above statistical analysis, we can see that the difference among these three matching tasks was quite significant. Further analysis revealed that MAT.RT(B) was significantly different from MAT.RT(C). $\text{MAT.RT(B)} < \text{MAT.RT(C)}$. This means that when subjects were matching pictures with homophones, it took a significantly longer time than that of matching pictures with entirely irrelevant characters. The characters used for MAT.RT(B) had a similar number of strokes to those used for MAT.RT(C), and also the two tasks' characters had quite a similar range of frequencies of usage. In such controlled conditions, $\text{MAT.RT(B)} < \text{MAT.RT(C)}$ indicated that there was a phonological interference when subjects were matching pictures with homophones. Thus there is strong reason for believing in the existence of phonological recoding in the processes of recognizing Chinese characters.

This result is consistent with those of Zheng(1973) and Tzeng(1977). It seems that the existence of the phonological process in recognition of Chinese characters is a reality even though there is no grapheme-phoneme correspondence.

CONCLUSION

Experiment 1 showed that the presence of a *homophone* distractor significantly slowed a picture-matching decision, indicating phonological interference where the task did not require phonological processing. This implies that a phonological route exists when one is reading Chinese characters though it is still not clear whether this route is an obligatory or not. Successive

presentation of picture then character may have induced a strategy of current picture naming, though the presentation durations make this perhaps unlikely.

3.3. LATERALISATION OF READING CHINESE CHARACTERS

INTRODUCTION

The lateralization of reading is an important issue in reading studies which should not be ignored. The significance of the study on the lateralization of reading Chinese characters is apparent: since there is a great difference between Chinese characters and alphabetic words in configuration (the complicated structures of Chinese characters--especially some picture-like features of them--make Chinese characters very different from alphabetic words). Lateralization in reading Chinese characters may give some important information about the universal properties of the reading process and about the script dependent properties of the reading process as well.

As we have seen in Chapter 1, the lateralization of reading has been studied in alphabetic scripts and alphabetic script users. In such research, the lateralization in reading is manifested by showing a general left hemisphere advantage for word recognition and word naming (Babkoff and Ben-Uriah, 1983; Barry, 1981; Chiarello, Dronkers and Hardyck, 1984; Hardyck et al., 1985; Leiber, 1976; McKeever and Hoff, 1982). The results show that left hemisphere advantage occurs no matter whether words are presented in a unilateral or a bilateral fashion (Boles, 1983; McKeever,

1971; McKeever and Huling, 1971). Moreover, the relationship between the phonological process and the lateralization has been suggested (Axelroad, Haryadi and Leiber, 1977; Bryden, 1970; ect.). For some studies on Japanese and Chinese characters, the results are, however, not consistent. There was research which found a right hemisphere advantage for Kanji and a left hemisphere advantage for Kana (Hatta, 1977). While there was also research which failed to reveal a significant right hemisphere advantage for Kanji (Sasanuma, Itoh, Mori, and Kobayashi 1977). In reading Chinese, there have been three kinds of results obtained from experiments of reading single Chinese characters: a. left hemisphere advantage (Zhang and Peng, 1984); b. right hemisphere advantage (Tzeng, et al. 1978); c. no hemisphere differences (Huang and Jones, 1980). Consequently the issue of how the brain functions when reading non-alphabetic scripts is still a heated topic in reading studies. This issue becomes more important if we put our attention to the relationship between the phonological process and the lateralization. Although this relationship is closely related to the routes used in the reading process, no research has been done yet. Therefore, in conjunction with my first experimental study on the phonological recoding in reading Chinese characters, I need further research on the relationship between this phonological recoding and lateralisation.

Four experiments were undertaken. All of these experiments were visual half field tests using a T-scope. The principle of visual half field tests is as follows: on the basis of the anatomy

of human visual system, optic nerves project stimuli from the left visual field to the visual cortex of the right cerebral hemisphere and the stimuli in the right visual field to the left cerebral hemisphere. In most studies of normal people LVF and RVF positioning is achieved by presenting stimuli tachistoscopically for less than the time needed to make an eye movement (around 150 ms) whilst the subject fixates centrally (see Young, 1982).

The first experiment used real Chinese characters, non-characters and pseudo-characters for subjects to identify; the second experiment was a naming test in which the same real Chinese characters were used for subjects to pronounce; *the third and fourth* experiments employed antonyms and homophones as materials for subjects to make a meaning judgment and a sound judgment. These *four* experiments were inter-connected for the purpose of examining the relationship between the phonological process and lateralization.

The first experiment was designed to examine if there is any lateralization in the recognition of Chinese characters without a task-defined need for phonological processing. It required the subjects to identify Chinese characters by distinguishing real Chinese characters from pseudo-characters and non-characters; the second one put stress on the involvement of articulation in reading by naming the real Chinese characters; the third and fourth put stress on the comparison between sound identification and meaning identification in reading.

3.3.1 LATERALISATION OF RECOGNITION (EXPERIMENT TWO)

The aim of this experiment is to examine any visual field differences in the recognition of real Chinese characters, pseudo-characters and non-characters in the reading process. There have been arguments regarding whether there is any hemisphere asymmetry in recognising Chinese characters based on visual field studies.

METHOD

Subjects:

24 native Chinese speakers. All of them came from the People's Republic of China to study in London as postgraduates or visiting scholars.

Sex: half of the subjects were male and half of the subjects were female.

Handedness: all of them were right handed.

Education: All of them were highly educated, all having graduated from college or university in China.

Materials:

Three kinds of stimuli were used in this experiment.

(1) Real Chinese characters. Number: 20.

(2) Pseudo-characters. Number: 20.

(3) Non-characters. Number: 20.

Examples of these three kinds of stimuli are illustrated below:

桶

(Real)

裡

(Pseudo)

罍

(Non)

A pseudo-character is a character-like symbol made by strokes, conforming to the rules of constructing Chinese characters.

A non-character is a symbol made by strokes which does not look like a Chinese character in that it is not formed by following the rules of construction in Chinese characters.

All the real Chinese characters, pseudo-characters and non-characters are the same structure type, they are compound characters or "characters" and are all organized in a way of left + right, that is: two radicals used as two components in forming them, one is located on the left side the other located on the right side.

Pseudo-characters and non-characters are constructed by some of the same components of characters, i. e. radicals. The difference between them lies in the ways by which they are formed: pseudo-characters have a legal localization for their radicals while non-characters have an illegal localization for the same radicals.

Real Chinese characters also have radicals in common with pseudo-characters and non-characters. Real Chinese characters used in the experiment are all commonly used ones. The number of strokes used in constructing pseudo-characters and non-characters are similar to that in real Chinese characters.

The stimulus was first made on one side of a card and then made into slides for use with the equipment in the experiment. In the middle of the card there was a number from the range 1 to 9.

All the stimuli (real Chinese characters, pseudo-characters, and non-characters) were the same size, i.e. 12*12 mm. The number in the middle of the slide was 4 * 6 mm in size. The distance between the middle of the character and the middle of the slide was 20 mm.

Equipment:

T-scope: A projector with an electronic shutter. The exposure time of the shutter was 150 ms. Between the subjects and the projector there was a half transparent screen where the image of stimuli was projected. The distance between subject and the screen was 48 cm. The stimuli were to be projected at 2° to the right or left of the middle point of the screen.

Two buttons were used as reaction keys.

A timer was used which was connected with both the projector and reaction buttons.

Procedure:

In the experiment, subjects were required to sit in front of the screen. In the middle of the screen, there was a fixation point where a number in the middle of the photographic frame was projected and which the subject was required to look at for the purpose of laterally projecting the stimulus. The presentation time for the unilateral stimulus was 150 ms.

Shortly before the experiment started, the examiner gave the subjects a preparatory signal which was a word in Chinese (准备 meaning "attention please"). Soon after this, the stimulus was projected. Subjects were asked firstly to make a reaction as to whether the stimulus was a real Chinese character or not by

selecting between two buttons to press as soon as possible: if the stimulus was a real Chinese character, then the red button should be pressed; if the stimulus was not a real Chinese character, i. e. either a pseudo-character or a non-character, then the black button should be pressed. Secondly, they had to report the number which appeared on the middle of the screen, in order to discern whether they had looked at the middle of the screen or not.

The reaction time was recorded by the timer from the moment the stimulus was projected to the time when the response button was pressed. Whether the subject's response for the stimulus was correct or not was recorded on a protocol, and whether the response for the number in the middle of the screen was correct or not was also recorded.

The instruction given to the subjects is the following:

"Please look at the mark in the middle of the screen. Soon there will be a character which could be a real Chinese character or a pseudo-character or a non-character projected on one side of the mark, and there also will be a number appearing on the mark. Your task is to make a judgment as to whether the character you see is a real Chinese character or not, if it is a real Chinese character then press the red button, if it is not, i. e. either being a pseudo-character or a non-character, then press the black button, and you are required to make such response as soon as possible; when you have pressed the button please report the number in the middle of the screen."

Before the real experiment began, the subjects were required

to do a trial with 12 stimuli (real Chinese characters, pseudo-characters and non-characters) presented to them as in the real experiment to let the subjects to get used to an experimental environment and the task requirements.

RESULTS

Twenty four subjects' reaction times and right and wrong responses were recorded and analyzed by using the BBC computer statistical package UNISTAT2.

The mean reaction times of each individual subject for real Chinese characters, non-characters and pseudo-characters (either presented in the left or right visual field) was calculated and presented in table 1 in appendix A (2).

The rate of mistakes in either visual fields when recognizing real, or pseudo, or non-characters was calculated and presented in the Table 2 in Appendix A (2).

Table 3.3. T tests of RTs for paired left versus right visual fields in recognizing real, or pseudo, or non characters

	R		N		P	
	LVF	RVF	LVF	RVF	LVF	R V F
mean	0.988	1.003	0.995	1.042	1.116	1.092
SD	0.216	0.242	0.198	0.224	0.255	0.333
t	0.594		2.320		0.410	
p	>0.25		<0.025		>0.25	

From the table, we can see there were no significant visual field differences in recognizing real Chinese characters and in recognizing pseudo-characters. In recognizing non-characters,

there was a significant visual field difference at 0.025 p level (two tailed) which showed an advantage for recognizing non-characters in right visual field.

Table 3.4. T tests of rate of wrong reactions for paired left versus right visual fields in recognizing real, or pseudo, or non characters

	R		N		P	
	LVF	RVF	LVF	RVF	LVF	RVF
mean	0.17	0.16	0.15	0.16	0.38	0.44
SD	0.11	0.10	0.12	0.13	0.15	0.21
t	0.34		0.25		1.35	
p	>0.25		>0.25		>0.05	

As we can see from the table, there was no significant differences between the left visual field rate and the right visual field rate.

To see if there were any correlations between the RT and the rate of accuracy, correlation tests were carried out. The results were as follows: the Pearson's coefficient, r , of RT with the rate of accuracy in the left visual field for recognizing real Chinese characters was 0.1420; the r of RT with that in the right visual field for real Chinese characters was -0.0814; the r of RT with that in the left visual field for non-characters was 0.0445; the r of RT with that in the right visual field for non-characters was 0.0331; the r of RT with that in left visual field for pseudo-characters was 0.0654; the r of RT with that in the right visual field for pseudo-characters was -0.0862. Apparently, there was no significant correlation between the RT and the rate of accuracy in

either visual field for each of the three stimuli.

In this experiment, three types of stimuli were used (real, pseudo, and non characters); the subjects were divided into two groups by sex; and the responses were required to be made in two different manners (the manner in which the right hand was to be used, and the manner in which the left hand was to be used). Therefore, to see if there were any differences by the types of stimuli, or by sex or by hand, a multi-way analysis of variance on the data was carried out. The results were as follows: There was a significant difference among RT for different stimuli in the left visual field, $F = 14.23346$, $P < 0.001$. Further details of these differences were: the difference between real characters and pseudo-characters was significant, $t = 3.622$, $p < 0.005$ (two tailed); the difference between non-characters and pseudo-characters was significant, $t = 4.876$, $p < 0.001$ (two tailed). There was a significant difference among the rates of accuracy for different stimuli either in the left visual field or in the right visual field. In the left visual field, $F = 31.02669$, $p < 0.001$; in the right visual field, $F = 35.56794$, $p < 0.001$. Further details of these differences were: the difference between real characters and pseudo-characters in the left visual field was significant: $t = 5.355$, $p < 0.001$ (two tailed); the difference between non characters and pseudo-characters in the left visual field was significant, $t = 6.914$, $p < 0.001$ (two tailed); the difference between real characters and pseudo-characters in the right visual field was significant, $t = 5.552$, $p < 0.001$ (two

tailed); the difference between non-characters and pseudo-characters in the right visual field was significant, $t = 7.696$, $p < 0.001$ (two tailed). The detailed results of these multi-way analysis of variances were represented in table 3, table 4, table 5 and table 6 in appendix A (2).

DISCUSSION

In this experiment, no RT differences between the left visual field and the right visual field were found in recognizing real Chinese characters and in recognizing pseudo-characters. The same results were found when examining the rates of accuracy between the left visual field and the right visual field in recognizing real Chinese characters, in recognizing pseudo-characters and in recognizing non-characters. But, in recognizing non-characters a significant RT difference between the left visual field and the right visual field was found where the advantage was given to the right visual field. These results do not support the view that the left visual field-right hemisphere is specialized for dealing with single Chinese characters as found in some experiments (e.g. Tzeng, et al., 1978). In contrast, when there was a visual field difference, the superiority was given to the left hemisphere which seems to be in favour of the view that the left hemisphere is specialized for dealing with single characters (e.g. Zhang and Peng, 1984). However the evidence for this visual difference is not very strong. Only in recognizing non-characters was the difference revealed. The reason for this may be that the LH was unable to generate a pronunciation and so could speedily decide that no word had appeared. Nevertheless, there is strong evidence that

supports the view that the two hemispheres both have the ability to deal with single Chinese characters. Both performances in recognizing real Chinese characters and pseudo-characters failed to show any significant difference between the two visual fields.

Although there were no obvious differences between the two visual fields, there were significant differences for dealing with different stimuli.

Sex and response manner were revealed to be insignificant factors in the subjects' performance. Both RT and the rate of accuracy were not influenced by either the sex factor or the response manner factor.

Returning to the basic requirement in performing this experiment, that is to recognise the differences amongst the Chinese characters, pseudo-characters and non-characters: this is a lexical decision task. It is of course different from a general reading aloud process. Articulation is not involved in this task. Therefore, one question is asked: could there be some difference when pronunciation is involved in the experiment? To test this a further experiment is needed.

3.3.2. LATERALISATION OF ARTICULATORY PROCESSES (EXPERIMENT THREE)

In experiment 2 no significant visual differences were found. A question raised from there follows: if there is no lateralisation in recognition of Chinese characters, we should examine whether the lateralisation is due to the articulation factor. To investigate

this, a naming experiment which involves articulation is needed. Experiment 3 was aimed at examining any visual field difference in naming real Chinese characters.

METHOD

Subjects:

24 native Chinese speakers. All of them came from the People's Republic of China to study in London as postgraduates or visiting scholars.

Sex: half of the subjects were male and half of the subjects were female.

Handedness: all of them were right handed.

Education: all of them were highly educated, they all graduated from college or university in China.

Materials:

There were 20 real Chinese characters used here for the subjects to pronounce. The stimuli were exactly the same as the real characters used in experiment 2.

Equipment:

T-scope: it was the same as that used in experiment 2. The same exposure time for stimuli (150 ms), and the same visual angle (2°) used here.

Instead of reaction buttons, A voice key with a microphone attached to the subjects throat was used in this experiment. When an articulation was made by subjects, the voice key was triggered.

A timer was used which was connected with the projector and the voice key.

Procedure:

In the experiment the subjects were required to sit in front of the projector as in experiment two. A voice key was put on the subjects' throat. There was a half transparent screen located between the subject and projector. Subjects were required to look at a mark in the middle of the screen which was the point where a number was projected. Asking subjects to look at the mark was for the purpose of letting the reading stimulus be laterally presented to them. The reading stimulus was a real Chinese character which was projected at 2° onto one side of the mark (either left or right randomly). As in experiment two, the presentation time for the unilateral stimulus was 150 ms.

Shortly before the experiment started, the examiner gave the subjects a preparatory signal, which was a Chinese word just as in experiment two. The task of the subjects was to read aloud the real Chinese character they saw as soon as possible with the eyes focusing on the middle of the screen. When they had pronounced the real Chinese character they also had to report the number they had focused their eyes on.

The reaction time was recorded by the timer, from the start of projecting the stimulus until the pronunciation was made. Whether the response of a subject was correct or not was recorded on the protocol, and whether the response of a subject regarding the number on the screen was correct or not was also recorded.

The instruction given to the subjects before the experiment is the following: "Please look at the mark in the middle of the

screen. Soon there will be a real Chinese character projected onto one side of the mark, either left or right randomly, and there will also be a number appearing on the mark. Your task is to read aloud the character as soon as possible, and when you have pronounced the character please also report the number in the middle of the screen".

Before the real experiment started, the subjects were required to do a trial with 4 characters presented to them so as to let them get used to experiment environment and task requirements.

RESULTS

Twenty four subjects' naming reaction times and the right and wrong responses were recorded and analyzed by using the BBC computer statistical package, UNISTAT2.

The subjects' mean naming reaction times were calculated and presented in table 1 in appendix A (3).

A two-way analysis of variance was carried out on the data. The results are represented in table 3.5.

Table 3.5. Two way anova with one repeated measure for RTs in the naming test

DUE	DF	SSQ	MSQ	F
A	1	0.004196	0.004196	0.18974
ERR	22	0.486543	0.022116	
B	1	0.017374	0.017374	14.55387
A*B	1	0.000413	0.000413	0.34598
ERR	22	0.026262	0.001194	
TOT	47	0.534789		

In the table, A refers to the factor of sex, and B refers to the factor of visual field. As we can see, there is no sex difference in the RT of naming Chinese characters, but there is a significant difference between left and right visual field in the RT of naming Chinese characters: $F = 14.55387$, $P < 0.001$. To examine in detail the visual field difference, a paired t test was conducted and the results are as follows:

Table 3.6. T test for mean RT between left visual field and right visual field

	LVF	RVF
Mean	0.71107	0.67303
SD	0.09591	0.11532
t	3.8704	
P	< 0.0005	

From the table, we can see there is a significant visual field difference with the advantage given to the right visual field in naming Chinese characters: $t = 3.8704$, $P < 0.0005$ (two tailed).

The accuracy of each subject's naming performance in either condition -- stimulus being presented in the left visual field or stimulus being presented in the right visual field -- was calculated and presented in table 2 in appendix A (3).

To examine whether there is any visual difference in the rate of accuracy, a t test was used and produced the following results.

Table 3.7. T test for accuracy of naming between left visual field and right visual field

	LVF	RVF
Mean	0.11	0.07
SD	0.07	0.05
t	2.79	
P	< 0.01	

From the table, we can see, there is a significant difference in the accuracy of naming Chinese characters between the left and right visual field: $t = 2.79$, $P < 0.01$ (two tailed).

To see whether there is any correlation between RT and the accuracy of naming, a correlation test was carried out. The results are as follows: the Pearson's correlation coefficient, r , of RT with accuracy in the left visual field is 0.2956. The Pearson's correlation coefficient of RT with accuracy in the right visual field is 0.4241. It is clear that there is no close correlation between the RT and accuracy in either visual field in this naming experiment.

DISCUSSION

The results of this experiment show a significant visual field difference in naming Chinese characters. The superiority in this naming performance was given to the right visual field. In contrast to experiment 2 where a visual field difference was not found, the finding from this experiment seems to be in favour of an idea that when pronunciation is required a hemisphere difference

will be revealed.

The materials used in this experiment were the same as some of those employed in the experiment 2, the only difference between these two experiments for dealing with these materials was whether articulation was involved or not.

Reading is a complex performance which involves several functions. According to the dual route model, a lexical route and a phonological route are the basic components of this process. Obviously, reading and reading aloud are not the same task. In reading aloud, an output mechanism, i.e. articulation, is involved, while such output mechanism is not an obligatory component in some other kinds of reading task, such as silent reading or lexical decision. It is reasonable to say that reading aloud requires a phonological processing in the sense that articulation is based on phonological information. It is for the purpose of testing whether there is a hemisphere difference when articulation is required for reading Chinese characters that this experiment was carried out. We see that the results have given us a positive answer: there is hemisphere lateralization in reading aloud.

However the matter is still not clear, because we still do not know whether this hemisphere difference is particularly due to the involvement of articulation alone, or more generally, is due to the requirement for generating phonological information. To solve this problem, further experiments are needed.

The further experiments are concentrated on the question: does the lateralization in reading only happen when articulation is

required, or could it be the case that whenever the manipulating phonological information is required, the hemisphere difference will appear?

3.3.3. LATERALIZATION OF PHONOLOGICAL PROCESSING (EXPERIMENT FOUR)

In order to examine whether the hemisphere difference is particularly affiliated to pronunciation or generally due to the requirement of generating phonological information, this experiment was designed. In this experiment, real Chinese homophone characters were used as the stimuli. The subjects were required to make a judgement on whether the paired Chinese characters presented to them were homophone or not. In this task pronunciation was prohibited. The experiment was aimed at examining if there was any visual field difference in identifying homophonic characters when no articulation was required.

METHOD

Subjects:

24 native Chinese speakers, all of them came from the People's Republic of China to study in London as postgraduates or visiting scholars.

Sex: half of the subjects were male and half of the subjects were female.

Handedness: all of them were right handed.

Education: all of them were highly educated, they all graduated from college or university in China.

Materials:

The materials were 40 pairs of Chinese characters, of which half were homophone to their pairs, half were not.

The frequency of usage of the characters in homophone pairs was kept in a similar range to those in non-homophone pairs. They were all commonly used Chinese characters.

The number of strokes used in the characters in homophone pairs was also kept in a similar range to that in non-homophone pairs.

Equipment:

1. Two field T-scope

Field 1: For the purpose of concentrating subjects' attention on the central point of the visual view scope. There was a central fixation point in the first field.

Field 2: For the purpose of presenting the stimulus which was a pair of Chinese characters, either homophones to each other or not. The stimuli were presented to the subject at 2° to the right or left of the middle point in the field.

2. Timer

A timer was connected with the second field, i.e. when a stimulus was presented to the subject, the timer was simultaneously triggered. The timer started at the same moment as the

presentation of the stimulus began.

3. Reaction button

Subjects made a reaction by pressing the red or black buttons which were connected to the timer and would stop the timer.

Subjects used both hands to make a reaction, one was for "yes", one was for "no".

Procedure:

In the experiment subjects were required to sit in front of the T-scope looking through the view window. Two fields were used in the experiment. The first field was used for presenting a focusing point; the second field was used for presenting a stimulus which was a pair of Chinese characters, either homophones to each other or not. One of the characters in the pair was located in the middle of the field in exactly the same place as where the focusing mark used to be; the other was located at 2° to the right or left of the middle point in the field. The order of presentation was firstly the central focusing point, secondly the stimulus.

First field exposure time: 500 ms.

Second field exposure time: 150 ms.

Shortly before the experiment started, a preparatory signal was given to the subject by the examiner. Soon after this the testing trial began. The task of the subjects was to make a judgment as to whether the stimuli they saw were homophone pairs or not by selecting one of two reaction buttons as soon as possible: if they were homophonically paired then a red button should be

pressed; otherwise a black button should be pressed.

Whether the response for each stimulus by the subject was correct or wrong was recorded on the protocol.

The instruction given to the subjects is the following:

"Please look at the middle of the field. Soon there will be a mark which you are required to focus your eyes on. Shortly after this appears, there will be two Chinese characters presented in the field, one is in the place you are required to focus your eyes on, the other is on one side of the field, either left or right randomly. Your task is to make a judgment as to whether the presented two Chinese characters are homophone to each other or not by pressing one of two buttons as soon as possible: if they are homophones, then press the red button, if they are not, then press the black button."

Before the real experiment started, subjects were required to do a trial with 8 paired characters presented tachistoscopically as in the real experiment in order to let the subjects get used to the experimental environment and task requirements.

RESULTS

Twenty four subjects' reaction times for judging homophone pairs and the right and wrong responses were recorded and analyzed by using the BBC computer statistical package, UNISTAT2.

The average RT for judging homophone pairs by each subject was calculated and presented in the table 1 in appendix A(4).

In this experiment, there were three factors: visual fields,

hand used in responding, and sex, thus a multi-way analysis of variance was needed to see if these factors had any effect on the results.

Table 3.8. Three ways anova for RT in judging homophone pairs

DUE	DF	SSQ	MSQ	F
A	1	0.0523	0.0523	0.5727
B	1	0.2041	0.2041	2.2363
A*B	1	0.0015	0.0015	0.0159
ERR	20	1.8254	0.0913	
C	1	0.0177	0.0177	8.8078
A*C	1	0.0006	0.0006	0.3209
B*C	1	0.0025	0.0025	1.2404
A*B*C	1	0.0058	0.0058	2.8885
ERR	20	0.0402	0.0020	
TOT	47	2.1501		

In the table, A refers to the factor of right hand vs left hand; B refers to the factor of male vs female; and C refers to the factor of visual field. As we can see there is no significant difference between using left and using right hand, and there is no significant difference between sexes. However, there is a significant difference between the left and the right visual field in identifying Chinese homophone characters: $F = 8.8078$, $P < 0.01$.

To see the details of visual field differences, a paired t test was conducted and the results are as follows:

Table 3.9. T test for RT between the left visual field and right visual field

	LVF	RVF
Mean	0.931	0.893
SD	0.216	0.215
t	2.8785	
P	< 0.005	

From the table, we can see, there is a significant difference in the RT of identifying Chinese homophone characters between the left and right visual field: $t = 2.8785$, $P < 0.005$ (two tailed).

The accuracy of each subject's performance for judging homophone pairs in either visual field was calculated and represented in table 2 in the appendix A (4).

To examine whether there is any significant difference between the left visual field and the right visual field with regard to the rate of accuracy, a t test was carried out, and the results are as in the following table.

Table 3.10. T test for accuracy of performance in judging homophone pairs between the left visual field and the right visual field

	LVF	RVF
Mean	0.16	0.13
SD	0.09	0.07
t	1.9017	
P	< 0.05	

From the table, we can see, there is a significant difference at 0.05 level(two tailed) in the accuracy of identifying Chinese

homophone characters between the left and right visual field.

To see if there is any correlation between RT and the accuracy of performance in either visual field, a correlation coefficient was calculated and the results are as follows: the Pearson's correlation coefficient for RT and accuracy in the left visual field is - 0.2974; the Pearson's correlation coefficient for RT and accuracy in the right visual field is 0.0772. Apparently, there is no obvious correlation between the RT and the accuracy of performance in either visual field.

DISCUSSION

This experiment revealed a RT difference between the left visual field and the right visual field. The advantage was given to the right visual field.

The finding of this experiment indicates that the hemisphere difference is not restricted to the condition involving articulation. The hemisphere difference is manifested not only in the case where articulation is required but also in the case when manipulating phonological information is a basic requirement.

For a further test of this idea, a supplemental lateralization experiment is needed in which manipulating phonological information is not a necessity in the reading condition. It is important to look at this from both sides. Having found that there is a lateralization function in reading when manipulating phonological information as a basic necessity, it is necessary to find out whether the hemisphere difference still

exists when there is no such necessity in reading. Only if we have evidence from the two sides of the matter can a sound conclusion be derived.

3.3.4. LATERALISATION OF SEMANTIC PROCESSING (EXPERIMENT FIVE)

To accompany the homophone judgment experiment, this experiment was designed to test whether there is a hemisphere difference when manipulating phonological information is not obligatorily involved. In this experiment Chinese antonymous characters were used as the stimuli. The purpose is to see if there is any visual field difference in identifying the antonyms.

METHOD

Subjects:

24 native Chinese speakers. All of them came from the People's Republic of China to study in London as postgraduates or visiting scholars.

Sex: half of subjects were male and half of subjects were female.

Handedness: all of them were right handed.

Education: all of them were highly educated, all having graduated from college or university in China.

Materials:

The stimuli were 40 pairs of Chinese characters, of which half were antonyms of their pairs, half were not.

The frequency of usage of the characters in antonym pairs were kept in a similar range to that of the non-antonym pairs. They were all commonly-used Chinese characters.

The number of strokes used in the characters of antonym pairs were also kept in a similar range to that used in non-antonym pairs.

Equipment:

The equipment used here was exactly the same as that in the experiment of homophone judgement. They included a two field T-scope; a timer which was connected with the T-scope; and the reaction buttons. The two fields used in the experiment had the same function as that in the experiment of homophone judgement. Field 1 was for the purpose of concentrating the subjects' attention on the centre of the view window. Field 2 was for presenting the stimulus. The stimuli were to be presented to the subject at 2° to the left or the right of the middle in the field. In this experiment, the stimulus was a pair of Chinese characters, either antonym to each other or not. As in the experiment of homophone judgement, subjects made a reaction by pressing the red or black button which was connected to the timer and would stop the timer.

Procedure:

In the experiment subjects were required to sit in front of the T-scope looking through the view window. Two fields were used in the experiment. The first field was used for presenting a focusing point which was a mark on the middle of the card for the

purpose of focusing the eyes of the subjects on the middle of the field. The second field was used for presenting stimuli which were pairs of Chinese characters, either antonyms or not. One of the characters in the pair was located in the middle of the field exactly in the same place as where the focusing mark used to be; another was located at 2° to the right or left of the central point. The order of presentation was first the central focusing point, second the stimulus.

First field exposure time: 500 ms.

Second field exposure time: 150 ms.

Shortly before the experiment started, a preparatory signal was given to the subject by the examiner which was the Chinese word for "attention please", exactly as in the experiment 2. The task of the subjects was to make a judgment as to whether the stimuli they saw were antonym pairs or not by selecting to press one of two reaction buttons as soon as possible: if they were antonym paired then a red button should be pressed; otherwise a black button should be pressed.

The reaction time was recorded by a timer from the presentation of the stimuli, i. e. paired Chinese characters, to the response button being pressed. Whether the response for each stimulus by the subject was correct or wrong was recorded in the recording form.

The instruction given to the subjects is the following:

"Please look at the middle of the field. Soon there will be a mark which you are required to focus your eyes on. Shortly after this

appears, there will be two Chinese characters presented in the field: one is in the place you are required to focus your eyes on, the other is on one side of the field, either left or right randomly. Your task is to make a judgment as to whether the presented two Chinese characters are antonyms of each other or not by selecting to press one of the two reaction button as soon as possible. If they are antonyms, then press the red button, if they are not, then press the black button."

Before the real experiment started, the subjects were required to do a trial with 8 paired characters presented to them, as in the real situation, for them to respond to in order to let the subjects get used to experimental conditions and the task requirements.

RESULTS

Twenty four subjects' reaction times for judging antonym pairs and the right and wrong responses were recorded and analyzed by using the BBC computer statistical package, UNISTAT2.

The average reaction time for judging antonym pairs of each subject was calculated and presented in table 1 in appendix A (5).

In this experiment, there was a choice of which hand to use for the response, either right or left, consequently there was a division in the group of hand; and there was also a sex division amongst the subjects, half being male and half female. Thus three factors exist in this test, i.e. visual fields, hand used, and sex. Therefore a multi-way analysis of variance is needed to see if

there is any effect from these different factors.

Table 3. 11. Three ways anova with one repeat measure for RT in antonym judgment experiment

DUE	DF	SSQ	MSQ	F
A	1	0.003255	0.003255	0.28407
B	1	0.002019	0.002019	0.17613
A*B	1	0.009738	0.009738	0.84960
ERR	20	0.229250	0.011462	
C	1	0.000398	0.000398	0.88480
A*C	1	0.001527	0.001527	3.39012
B*C	1	0.000246	0.000246	0.54667
A*B*C	1	0.001390	0.001390	3.08656
ERR	20	0.009007	0.000450	
TOT	47	0.256830		

In the table, A refers to the factor of right hand vs left hand; B refers to the factor of male vs female; and C refers to the factor of visual field. As we can see, there is no significant difference between using left and using right hand, and there is no significant difference between sex. Moreover, there is also no significant difference between the left and the right visual field.

The accuracy of each subject's performance was calculated and presented in Table 2 in appendix A (5).

To see if there is any significant difference between the left visual field and right visual field with regard to the rate of accuracy, a t test was carried out. The results are as follows:

Table 3.12. T test for judging antonym pairs between the left visual field and right visual field

	LVF	RVF
Mean	0.11	0.11
SD	0.09	0.09
t	0.12	
P	> 0.25	

From the table, we can see that there is no significant difference in the accuracy of judging Chinese antonyms between the left and right visual field.

To see if there is any correlation between RT and accuracy for judging antonyms, a correlation coefficient is calculated: the Pearson's correlation coefficient for RT and accuracy in the left visual field is 0.4685; the Pearson's correlation coefficient for RT and accuracy in the right visual field is 0.1067. Apparently, there is no obvious correlation between the RT and the accuracy of judging Chinese antonyms in either visual field.

DISCUSSION

In this experiment no visual field difference is found for judging antonym pairs. It is obvious that to perform the task of judging antonyms what is essentially needed is understanding the meaning of the paired characters. It is on the basis of meaning rather than on the basis of phonological information that a correct judgment will be made. Therefore, this experiment provides evidence that there is a reading condition in which manipulating

phonological information is not necessarily involved and at the same time no hemisphere difference is found. The results of this experiment seem to indicate that the right hemisphere is to some extent capable of ascertaining the meaning of Chinese characters.

3.3.5. SUMMARY OF LATERALIZATION EXPERIMENTS

To sum up these visual field experiments, we can get a general picture of the lateralization of the brain in reading single Chinese characters. (a) In a "lexical decision" task, there was a general lack of visual field difference, but in identifying non-characters there was a right visual field advantage. (b) In the "reading aloud" task there was a right visual field advantage. (c) In the task of "identifying homophones" there was a right visual field advantage. (d) In the task of "identifying antonyms" there was no visual field difference. Four conclusions can be drawn from these results:

1. No left visual field advantage has been found in all the tasks. This implies that in dealing with written information, the right hemisphere seems not to be dominant.

2. The right hemisphere, however, seems to have capacity of dealing with Chinese characters in two tasks: one is in lexical decisions, the other is in meaning judgments.

3. Lateralization seems to be related to manipulating phonological information in reading. One thing is common in both reading aloud and identifying homophone characters: the generation

or manipulation of phonological information is obligatory. In these two tasks a right visual field advantage was found. But when generating or manipulating phonological information is not obligatory the hemisphere difference disappears. One thing is common in both lexical decision and identifying antonymous characters: in these two tasks, phonological information is not required. Whether a character is a legal character can be judged on the basis of the configuration aspect of the character. Whether paired characters are antonyms of each other must be decided on the basis on their semantic content. In these two tasks no visual field advantage was found.

4. There seems to be a universal mechanism in reading lateralization in relation to phonology. The findings of these experiments implies the importance of phonology in lateralization. It indicates something about the nature of lateralization. These results are in line with the notion that the left hemisphere is functionally specialized to deal with phonological information. Therefore when a task requires manipulating phonological information the superiority of the left hemisphere is manifested.

5. There is a script effect in reading lateralization. This can be seen clearly when we compare these experiments of reading Chinese characters with the studies on the lateralization in reading alphabetic languages. In research on lateralization in reading alphabetic languages, the main finding is that the left hemisphere has the superiority in dealing with them. Even in lexical decision tasks, a RVF superiority is also found (Babkoff

and Ben-Uriah, 1983; Barry, 1981; Chiarello, Dronkers and Hardyck, 1984; etc.). In research on lateralisation in reading Chinese characters, no consistent results have been found yet. In my experiments on reading Chinese characters, no visual field differences were found in some aspects of reading.

3.4. NORMAL ERRORS IN SPEEDED READING (EXPERIMENT SIX)

INTRODUCTION

It is known that in users of alphabetic languages types of error characterise types of dyslexia. In surface dyslexia, a critical symptom is regularization errors; in deep dyslexia, a critical symptom is semantic errors. In the studies on Japanese patients there have been some reports in which the semantic errors only happen when they were reading Kanji but not Kana (Coltheart, M. 1980; Sasanuma, S. 1980). As for surface dyslexia there has been a report on a Japanese patient who might be classified as a kind of surface dyslexia (Sasanuma, S. 1980). As for Chinese readers, unfortunately, there have been no reports on deep or surface dyslexic cases yet. Due to great differences between alphabetic languages and Chinese characters, to investigate whether deep and surface dyslexia exist in Chinese readers will be valuable.

However, it is necessary to establish in normal readers, whether reading errors characteristic of the dyslexias -- i.e.

regularisation or semantic errors -- can be found. To my knowledge, there have been no reports of "normal" semantic errors in either alphabetic readers or Chinese readers.

DESIGN

With the above in mind, a quite natural experiment was designed: Chinese subjects (Mandarin and Cantonese speakers) were required to read a list of single Chinese characters or non-characters in Mandarin pronunciation in a speeded reading condition. The reason for including Cantonese speakers was to study the reading process when the phonological code is not well set up.

An observation on a Cantonese's reading of Chinese characters showed that there were many semantic errors in his reading and the possible reason might be that he had not got a well established Mandarin phonological code to assist his reading. There were also other requirements for this experiment. The characters should be different kinds in order to elicit the reading phenomena. For example, irregular pronunciation also exists in Chinese reading and the phonological route will be explored when one is reading irregular characters. Moreover, since non-words are important for eliciting reading symptoms, it will be necessary to include them.

Subjects:

The subjects were grouped into two kinds: those who speak Mandarin as their first language and those who speak Cantonese as their first language. There were eight Mandarin speakers and four

Cantonese speakers who could read and speak some Mandarin. Half of the Mandarin speakers were men and half women. The age range was from 23 to 36. All of the Cantonese speakers were women aged from 22 to 28. All of the Mandarin speakers were born and grew up in Mainland China. Their education level was university graduate. Two of the Cantonese speakers were born in Guangdong province in Mainland China but grew up in Hongkong. The other two Cantonese speakers were born and grew up in Hongkong. Three of the Cantonese speakers finished their high school in Hongkong. One Cantonese speaker graduated from university. All of the Mandarin speakers knew at least 4000 Chinese characters as they themselves said. All of the Cantonese speakers stated that they knew about the same number of Chinese characters but could not pronounce all of them in Mandarin.

Material:

The reading material consisted of 408 Chinese characters and 74 non-words which looked just like Chinese characters and it is probably better to regard them as pseudo-characters. Among the 408 characters there were 18 irregular characters. Irregular characters refer to the pictophonetic characters which are pronounced differently from their phonetics. Such as 埋 "bury" which is pronounced [mái] while its phonetic "里" has a sound [lǐ]. Opposite to irregular characters are the regular characters which refer to the pictophonetic characters which are pronounced the same as their phonetics. Such as 炬 "torch" pronounced [jù] which is the same as the pronunciation of its phonetic "巨". The

irregular characters used in the experiment were: 巢 "nest" [chāo], 埋 "bury" [mái], 析 "analyze" [xī], 盼 "expect" [pàn], 扮 "be dressed up as" [bàn], 媒 "matchmaker" [méi], 怕 "be afraid of" [pà], 帕 "handkerchief" [pà], 沙 "sand" [shā], 暗 "dim" [àn], 胖 "fat" [pàng], 泪 "tear" [lèi], 杯 "cup" [bēi], 靴 "boots" [xuē], 洽 "agree" [qià], 冶 "smelt" [yě], 治 "govern" [zhì], 概 "approximate" [gài]. 74 pseudo-characters (non-words) were divided into two groups. One was the pseudo-character with sound radical. Another was the pseudo-character without sound radical. The number of pseudo-characters without sound radical were 20 in all. They were: 由, 石, 半, 殳, 苦, 壺, 艹, 攷, 汴, 紉, 宀, 殳, 夫, 存, 耒, 咎, 攷, 别, 邇, 邾.

Procedure:

The subjects were asked to read the material aloud and as fast as they could. An instruction was given to them before the experiment started. The instruction was: "Read the characters on the paper as fast as you can. If you meet characters which you don't know, just omit them; or if you can pronounce them, just pronounce them."

RESULT AND DISCUSSION

The reading material was given to Eight Mandarin speakers and four Cantonese speakers to read. The experiment was conducted on an individual basis, i.e. one subject at a time. The reading performance of the subjects was recorded by a tape recorder. The

results were then analyzed by examining the records.

Table 3.13. The numbers of errors of different types made by each subject

Subjects	Sem.	Re(ps).	Er(p).	Re(ir).	Visual.	Others
WU(M)	0	4	0	0	0	
QUAN(M)	0	18	0	0	0	
LI(M)	0	15	1	0	2	
CHA(M)	0	2	0	1	2	
SUEN(M)	1	29	0	8	3	
CHENG(M)	1	23	0	1	8	
QI(M)	2	13	1	1	2	
LIANG(M)	3	6	1	1	2	
XIAOa(C)	2	18	0	0	3	
LU(C)	3	28	3	2	2	
JIAO(C)	3	9	0	4	6	
XIAOb(C)	6	26	0	9	5	

In the table, the letter in the bracket beside each subject indicates whether the subject is Mandarin speaker or Cantonese speaker, i.e. "M" stands for Mandarin speaker, "C" stands for Cantonese speakers. "Sem" stands for semantic errors. "Re(ps)" stands for the "regularisation errors" made in reading pseudo-characters with sound radicals. Here, "regularisation error" means that the subject read a pseudo-character (non-word) as how its sound radical is pronounced. "Er(p)" stands for errors made in reading pseudo-characters without sound radicals. "Re(ir)" stands for the regularisation errors made in reading irregular words.

"Visual" stands for visual errors. "Others" stands for other kinds of errors.

Among the eight Mandarin speakers there were four people who made semantic errors. All of the Cantonese speakers made semantic errors. The number of semantic errors made by Mandarin speakers was from 1 to 3 while that made by Cantonese was 2 to 6. It seems that making semantic errors when speed reading Chinese characters in Mandarin is more common in Cantonese speakers than in Mandarin speakers. Nevertheless, that half of Mandarin speakers made semantic errors indicates that making semantic errors is a striking phenomenon which should not be neglected. The semantic errors made by subjects were: 巢 "nest" [cháo] -- 穴 "nest" [xüè] (Suen); 唇 "lip" [chún] -- 舌 "tongue" [shé] (Cheng); 护 "protect" [hù] -- 防 "prevent" [fáng], 狸 "fox" [lí] -- 狐 "fox" [hú] (Qi); 想 "think" [xiǎng] -- 思 "think" [sī], 窝 "nest" [wō] -- 巢 "nest" [cháo], 询 "ask" [xún] -- 咨 "consult" [zī] (Liang); 析 "analyze" [xì] -- 解 "untie" [jiě], 绳 "rope" [shéng] -- 长 "long" [cháng] (Xiao1); 丢 "lose" [diū] -- 掉 "fall" [diào], 匙 "spoon" [shí] -- 勺 "spoon" [sháo], 翻 "jump" [fān] -- 欢 "joy" [huān] (Lu); 暗 "dim" [àn] -- 黑 "dark" [hēi], 匙 "spoon" [shí] -- 勺 "spoon" [sháo], 护 "protect" [hù] -- 搂 "hug" [lǒu] (Jiao); 析 "analyze" [xì] -- 解 "untie" [jiě], 握 "hold" [wò] -- 抓 "grasp" [zhuā], 蚂 "ant" [mǎ] -- 蚁 "ant" [yǐ], 护 "protect" [hù] -- 牢 "solid" [láo], 鲸 "whale" [jīng] -- 鱼 "fish" [yú], 火 "flame" [yán] -- 火 "fire" [huǒ] (Xiao).

Coltheart (1980) convincingly demonstrated that there are two different types of semantic errors in reading alphabetic words by deep dyslexia. One is the shared-feature semantic errors, such as: bush-tree, cattle-animals, hours-time, dad-father. The other is the associative semantic errors, such as: cone-ice cream, shining-sun, wear-clothes, wrist-watch. Could this classification of semantic errors made by deep dyslexia of alphabetic readers also be applicable to the errors made by normal Chinese readers? A positive answer to this question is given by the following analysis.

It seemed that the semantic errors made by Chinese readers can also be generally divided into two categories. One is the errors which share some semantic features with the stimuli. The other is the errors which associate with stimuli in certain ways. In the first category, the errors can be further divided into four types: the first type is the accompanied synonym in which the errors and stimuli are very often used together, whilst each word has the same or similar meaning, such as: 想 "think" [xiǎng] -- 思 "think" [sī], usually used as 思想 "thought"; 狸 "fox" [lí] -- 狐 "fox" [hú], usually used as 狐狸 "fox"; 蚂 "ant" [mǎ] -- 蚁 "ant" [yǐ], usually used as 蚂蚁 "ant". The second types is the synonym in which the errors and stimuli can be used in the same semantic situation but usually appear alone, such as: 巢 "nest" [cháo] -- 穴 "nest" [xué], 暗 "dim" [àn] -- 黑 "dark" [hēi], 匙 "spoon" [shí] -- 勺 "spoon" [sháo]. The third type is the words which have similar meaning but

are not exact synonyms, such as: 护 "protect" [hù] -- 防 "prevent" [fáng], 析 "analyze" [xī] -- 解 "untie" [jiě], 丢 "lose" [diū] -- 掉 "fall" [diào]. The fourth type is the relation words. They can be linked within the scope of similar movements, like 握 "hold" [wò] -- 抓 "grasp" [zhuā], 护 "protect" [hù] -- 搂 "hug" [lōu]; or in the domain of similar things such as: 鲸 "whale" [jīng] -- 鱼 "fish" [yú], 唇 "lip" [chún] -- 舌 "tongue" [shé]. In the second category, the semantic errors and stimuli did not share the same semantic feature but were linked by associative relations. They could be associated in terms of cause and result such as: 炎 "flame" [yán] -- 火 "fire" [huǒ], 翻 "jump" [fān] -- 欢 "joy" [huān], or associated in terms of related feature such as: 绳 "rope" [shéng] -- 长 "long" [cháng]. It is apparent that the two categories of the relationships between semantic errors and stimuli made by normal Chinese readers are generally correspond to those made by deep dyslexia in alphabetic readers.

In all these semantic errors, about 20 per cent (4/21) shared the same significs with the stimuli (all the stimuli which produced semantic errors are combination-form except two which are single-graphs). They are: 狸 "fox" -- 狐 "fox" while 犛 is the signific; 想 "think" -- 思 "think" while 心 is the signific; 护 "protect" -- 搂 "hug" while 扌 is the signific; 蚂 "ant" -- 蚁 "ant" while 虫 is the signific. It seems that there might be a relationship between the signific and semantic errors but such a relationship is not apparent.

For 54 pseudo-characters with sound radicals, the subjects very often just read the sound radicals out, regarding the sounds as the pronunciation for the pseudo-characters. So it showed clearly that the sound radicals, as the components of characters, have a significant role in representing the sounds of the characters. This is evidence against the common idea that Chinese character do not represent sound. Although this evidence came from the performance of the reading of non-words, it did indicate that sound radicals can be detected and pronounced as the sound of the words they represented. In fact, there are over 80 % Chinese characters having sound parts and therefore their sound can be judged more or less by the sound parts. However, as my analysis of the phonological structure of Chinese characters (Chapter 2) shows, although Chinese characters do have a way to represent their sounds, this method is not perfect in terms of reliability or accuracy because CRP (the ratio of completely representing sound in all phonetics) is only 0.36. Therefore, it is not surprising that the subjects often made the wrong pronunciation by taking the sound of sound radical as the pronunciation of pseudo-characters. This phenomenon is quite like surface dyslexia in which regularization happens when patients are reading irregular words.

For 20 non-words without sound radicals, the subjects could hardly read them out. Among eight Mandarin speakers, three pronounced a same non-word out which was 夫 . They read it as 夫 . It seems more like a visual misunderstanding rather than a spoken non-word. One of the four Cantonese speakers pronounced

three non-words, they were: 夫 -- 夫 (same as mentioned just before), 半 read as 尔, 殁 pronounced as 矢委. The pronunciation for the last two non-words is difficult to explain but still looks like a visual misunderstanding. Visual errors seem to be a common phenomenon among the subjects. All but two of the subjects had this problem. The amount of these errors were similar (see table 3.13).

Chinese exceptional words or irregularly pronounced characters have not received enough attention. Yet, they are important to the studying of reading processes precisely because one of the key symptoms of surface dyslexia is how to deal with them. In this experiment irregular characters were usually pronounced correctly by the subjects, but there were some cases in which regularization appeared: among the eight Mandarin speakers, five made regularisation errors; among the four Cantonese speakers, three made the same errors.

The results of this experiment give us some hints for the routes in reading Chinese characters. First of all, as we have seen, more semantic errors were found in Cantonese speakers than in Mandarin speakers. It indicates that when the reader has a better access to phonology (when the subject's native language is Mandarin), the semantic errors were better prevented. This supports some explanations of semantic errors raised from multi-route model (e.g., Newcombe and Marshall, 1980), and thus indicates that there is a route to phonology that is independent of the route to meaning. Secondly, the existence of regularization in reading

Chinese characters gives us evidence of the existence of a sound radical-syllable conversion route in reading Chinese characters. The fact that regularisation errors appeared in reading pseudo-characters further indicates that this sound radical-syllable conversion route can be independent of the route to meaning. Thirdly, as for the existence of other route/routes in reading Chinese characters apart from the phonological route, there is some indirect evidence from this experiment. The existence of semantic errors indirectly shows that there is another route in reading Chinese characters apart from the phonological route. The better performance of Mandarin speakers over Cantonese speakers indirectly shows that there is a route to pronunciation through meaning. Moreover, considering the fact that no semantic errors made by normal subjects have been reported in reading alphabetic words, it might be reasonable to think that the other route(s) (apart from phonological route) is/are comparatively more often used in reading Chinese characters.

The results of this experiment also suggest a special feature in dealing with the configuration of the Chinese compound characters which are closely related to the performance of the phonological route in reading Chinese characters. It is: the compound Chinese characters can be read separately. There are two kinds of evidence for this: 1) What had been read in surface dyslexic symptom is the phonological radical. 2) What had been read in non-characters with sound radicals are also phonological radical. This implies that the sound radical, as the component of

the compound characters, can be recognized and read apart from the whole character. This reflects a reading feature in dealing with the configuration of Chinese characters which needs to be further studied.

CONCLUSION

1. Semantic errors happened when normal Chinese read Chinese characters under the condition of speed reading.

2. The sound radical can be pronounced as the sound of non-word. There is a phenomenon of regularization in the processing of reading irregular characters by subjects. These predict the existence of surface dyslexia in Chinese readers.

3. On the whole, the semantic errors and the regularization of reading irregular words happened more often among Cantonese speakers than Mandarin speakers. This shows the importance of a well established phonological route for preventing semantic error and regularization.

4. The implication of this experiment suggests that there is a route to phonology in reading Chinese characters which is independent of the route to meaning; and moreover, the processes of reading Chinese characters may be similar to that in reading alphabetic words in the sense that there might be a similar multi-route mechanism in the processes. To further confirm this prediction we need to do some clinical studies to find out if there are different routes in reading Chinese characters.

5. The results of this experiment also suggest that there is

a special feature in dealing with the configuration of Chinese characters which reflects the separability of reading Chinese combination-forms: the phonetic is completed on its own because it is a single-graph, and thus enables readers to read (pronounce) it as the sound of the whole combination-form.

CHAPTER 4

STUDY OF ACQUIRED CHINESE DYSLEXIA

4.1. INTRODUCTION

In research on acquired dyslexia among users of alphabetic writing systems, multiple reading routes have been identified. According to this multi-route theory, getting either sound or meaning from a word's form is achieved by more than one route. The essential routes in this theory are: first, a sublexical phonological route. This route maps a word's form to its sound via a sub-lexical mechanism, which assembles the component sounds into complex pronunciations. Second, a semantic route which maps a word's form directly to its meaning, and hence maps the meaning onto a whole word pronunciation; and third, a direct route which maps a word's form to its sound without grapheme-phoneme conversion and without semantic mediation. These routes are independent of each other. The evidence for these independent routes has been found mainly from several well defined acquired dyslexias in alphabetic language users: deep dyslexia, surface dyslexia and phonological dyslexia. If these reading routes are universal, we would expect them to be found exhibited in the process of reading Chinese characters as well. This being so, we would expect to find evidence to demonstrate the existence of these routes in Chinese acquired dyslexic patients.

In experimental studies on reading Chinese characters (chapter 3), we have obtained evidence from normal adults which

give us some indications of the routes involved in the process of reading Chinese characters and these routes are compatible with those we have already outlined above about the processes involved in the reading of alphabetic words. These studies showed, firstly, that semantic errors and regularization errors were found in normal adults when they were required to read a list of characters quickly. The existence of regularization indicates the possible use of a phonetic-syllable route in reading Chinese characters, and this implies that we might be able to find some patients who manifest reading symptoms by relying mainly on this route in reading Chinese characters. In other words, we might be able to test the existence of a reading route from the phonetic to sound in clinical studies. In contrast, the existence of semantic errors indicates the use of a semantic route in reading Chinese characters, and this implies that we might be able to find some patients who manifest reading symptoms by heavily relying on this route in reading Chinese characters. Secondly, phonological recoding was found in the picture-character matching experiment. This finding indicates the existence of a direct route from the character as a whole to its sound, because many of the characters used in the experiment were not pictophonetic (in other words, they did not have phonetics). This indicates the existence of a direct route from whole character to sound. Thus it implies that we might be able to find some clinical cases which demonstrate this "whole character" to sound route. On the whole, there are three routes implied by the experiment on normal subjects and these three routes

need to be tested in clinical studies.

Considering the obvious differences between alphabetic words and Chinese characters, there will be, of course, some detailed differences between the routes used in reading alphabetic words and the routes used in reading Chinese characters. As we know, there is no spelling-to-sound organization in the structure of Chinese characters, therefore to find an exact grapheme-phoneme conversion mechanism in reading Chinese characters will not be possible; but there is a phonological organization in the structure of most Chinese characters in which the phonology is represented by a phonetic but this does not map into phonemes but syllables. Thus, a counterpart to grapheme-phoneme mechanism might exist in reading Chinese characters which is phonetic-syllable conversion. Consequently, instead of finding a precise grapheme-phoneme conversion mechanism in the phonological route, we would be able to find a phonetic-syllable conversion mechanism in reading Chinese characters. In contrast to the phonological route, the semantic route and direct route between reading Chinese characters and reading alphabetic words seem to be analogous. It may only be the extent to which the routes are used that varies. The semantic route may be heavily used in reading Chinese characters due to the weakness in phonological representation in Chinese characters.

Moreover, in Chapter 2, we presented an analysis of Chinese characters from which the main characteristic of Chinese script, showed itself in structure and phonology. In the former, Chinese characters have a complex visual construction which can be divided

into four different types (pictographic, indicative, associative and pictophonetic characters) and each of these types has a unique way of representing its meaning. Among these four types, the pictophonetic one is the most numerous. In this dominant type, two components (signific and phonetic) correspond to meaning and sound to some extent. The above four types can again be divided into two constructional categories: single-graph and combination-form. It is important to remember that pictophonetic characters represent sound with variable accuracy and reliability; moreover, because the characters stand for monosyllables, homophones affect the way in which readers pass from the character to its sound and its meaning. These should be taken into consideration when testing the routes used in reading Chinese characters.

It is unfortunate that studies of reading Chinese characters in the clinical field have not yet been able to tackle the above issues. As we have seen from the literature reviewed, the research of Chinese acquired dyslexia has concentrated mainly on 4 issues: (1) The neural anatomy of Chinese reading disorders (Lyman, et al. 1938; Wang, et al. 1959; Tang, 1978; Hu, et al. 1983; Li, et al. 1984; Hu, et al. 1986). (2) Clinical classification according to whether dyslexia is accompanied by dysgraphia (Wang, et al. 1959; Tang, 1978; Wang, et al. 1981; Li, et al. 1984; Hu, et al. 1986). (3) The relationship between speaking ability and reading capacity (Hu, et al. 1983). (4) The levels of reading impairment, according to whether these were at the level of words or at the level of sentences (Hu, et al. 1986). However, for the main issues of

reading Chinese characters, i.e. the routes involved in the reading processes, these studies are insufficient.

Until now, the studies of Chinese reading have not determined if there are reading disorders which depend on the special characteristics of the Chinese script.

Bearing in mind the above considerations, we badly need to carry out a clinical research on reading Chinese characters to see if a multi-route model is also suitable to Chinese readers and if there are special characteristics in reading the Chinese script. To test whether or not reading Chinese characters is a multi-route process, we need to find the detailed performances of the different routes in Chinese patients. Thus, we need to examine the existence of the route from whole characters to sound, to examine the route from phonetics to sound, and to examine the route from characters to meaning without mediation of sound. It is also quite important in this clinical study, that in order to examine whether or not the phonological route exists in reading Chinese characters, we need to find out whether or not Chinese patients can have selective deficits, or sparing, of radical (phonetic) - syllable conversion, which corresponds to the grapheme-phoneme mechanism, in reading pictophonetic characters. In fact, this has been seen in the experimental studies in which regularization in the fast reading test(chapter 3) has demonstrated the possibility of using this mechanism in reading Chinese characters; and thus in the clinical field, we would expect to see a kind of acquired dyslexia in reading Chinese characters which is similar to surface dyslexia in

alphabetic languages users. Moreover, in order to examine whether or not the independent semantic route exists in reading Chinese characters, we need to find a kind of acquired dyslexia which is analogous to deep dyslexia of alphabetic languages users. As we have noted, the semantic errors have been seen in the experimental studies in which such errors in the fast reading test has suggested the use of the semantic route alone, unchecked by phonological information derived sublexically.

4.2. THE AIMS AND METHODS OF THE STUDY

The main aim of this study is to determine whether the multi-route model suggested by the experiments on normal readers can be supported with evidence of selective deficits in the proposed routes, and to see if novel forms of acquired dyslexia can be discerned which depend on script-specific features.

The test items were designed in four sets.

The first set examines whether or not reading Chinese characters is a multi-route process. In this first set, three routes are examined: one is the route from the whole character to sound; another is the sublexical phonological route; and finally there is the semantic route. The tests included here are as follows:

(1) The test of naming characters, naming pictures, and matching characters with pictures.

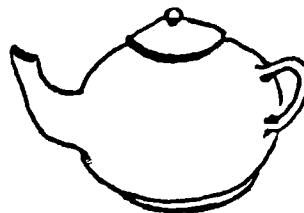
The purpose of this test is to examine whether the route from the character's form to its meaning and the route from the

character's form to its sound are independent. That is to test the direct route and the semantic route, thus revealing the relationship between a Chinese character's form, sound and meaning under conditions where brain damage blocks one route or the other.

This test requires patients to name common characters and corresponding pictures, and then to match them together. During the matching process, patients are given a Chinese character together with several pictures together (usually one character with four pictures); then the patients are asked to select the corresponding picture to match the character. There are 18 characters and 36 pictures. However, usually each patient will only be given 9 characters to read and match. An example of the characters and corresponding pictures are as follows:



"house" [fáng]



"kettle" [hú]

(2) The test of judging homophones and antonyms.

This is a supplementary test for examining selective impairment of the route for form to sound and form to meaning.

The example of homophones are as follows:

目 木
 "eye" "tree"
 \ /
 [mu]

立 力
 "stand" "strength"
 \ /
 [li]

The example of antonyms are as follows:

上	下	大	小
"up"	"down"	"large"	"small"

There are 12 homophone pairs and 12 antonym pairs.

(3) The test of semantic categorizing.

This is a supplementary test for examining the semantic route. It will reveal the relationship between a character's form, sound and meaning with special attention given to the degree of semantic comprehension.

The procedures followed in doing this test involve presenting the names of several objects from the same and different categories as well as the names of those categories, and then asking the patients to put the objects' names into the correct categories. For example, 苹果 "apple", 梨 "pear" should be put under 水果 "fruit"; 胡萝卜 "carrot" 西红柿 "tomato" should be put under 蔬菜 "vegetables" according to Chinese tradition.

There are 4 categories, which are animal, vegetable, famous peoples, and vehicles. Each category has 6 items.

(4) The test of reading regular, irregular, phonetic characters, and pseudo-characters.

The purpose of this test is to test if there is a sublexical route in reading Chinese characters. It will show a possible

analogue of the surface dyslexia in reading Chinese characters, that is, whether regularisation errors characterise some patients but not others. And it will show if some patients have special difficulties reading pseudocharacters (equivalent to nonwords in alphabetic scripts), the analogue of phonological dyslexia, and whether these patients are also the ones to make most semantic errors (like deep dyslexic patients).

Regular characters refer to those Pictophonetic characters which are pronounced the same as their phonetics. Such as 理 which is pronounced [lǐ], which is the same sound as its phonetic radical 里 which is also pronounced [lǐ]. 40 regular characters are used.

Irregular characters refer to those Pictophonetic characters which are pronounced differently from their phonetic radicals. Such as 埋 which is pronounced [mái] which is quite different from the sound of its phonetic radical 里 which is pronounced [lǐ]. 21 irregular characters are used.

Phonetic characters refer to those characters which can be used as phonetics in pictophonetic characters. Such as

分 means separate, pronounced [fēn], which can also be used as a phonetic in combination-form characters, for instance, in 芬 means fragrant, pronounced [fēn]. 12 phonetic characters are used.

Pseudo-characters refer to those symbols which look like Chinese characters but which are actually not real characters. Their structures and components fit the requirements of what a Chinese character should look like, and they include phonetics as

their components. Such as 剖 both 占 , a phonetic, and 丿 are real components of Chinese compound characters, and the arrangement of them in 剖 is in accordance with the principles for constructing Chinese characters. 12 pseudo-characters are used.

The second set of tests is to examine whether there is a basic pattern in recognizing Chinese characters. Tests included here are as follows:

(5) The test of judging non-characters and pseudo-characters.

The purpose of this test is to find out whether a basic recognition pattern of Chinese characters exists, that is, a basic structural frame of Chinese script which has a perceptual unity.

Non-characters refer to those symbols which do not follow the rules as how Chinese characters should be written, such as 另 both 另 and 丿 are legal radicals but the arrangement in 另 is illegal because 丿 cannot be placed on the right side. Pseudo-characters refer to those symbols which fit the requirements of how Chinese characters should look like, but they are not real characters, such as 伪 both 丿 and 另 are legal radicals, and their arrangement in 伪 is also legal, nevertheless, 伪 is not a real character.

6 non-characters, and 6 pseudo-characters are used.

(6) The test of discriminating overlapped characters.

The purpose of this test was the same as that in (7).

Examples of overlapped characters are as follows:

(one 马 horse, one 人 man, they were overlapped by being written together)

6 overlapped characters are used.

(7) The test of filling in strokes which were taken out of the characters.

The purpose of this test is the same as that in (6).

Examples of the characters with strokes missing are: 欠, 弓, etc. The task is to fill in missing strokes to form perfect characters.

There are 6 characters with strokes missing which are to be filled in by patients.

The third set of tests is to examine the special characteristics of Chinese acquired dyslexia. Tests included here are as follows:

(8) The test of reading single-graph characters and combination-form characters.

The purpose of this test was to find out whether there is a selective disorder in dealing with single-graph characters or combination-form characters.

Examples of single-graph characters are as follows:

木
"wood" [mù]

子
"son" [zǐ]

日
"sun" [rì]

月
"moon" [yuè]

Examples of combination-form characters are as follows:

李

"plum" [lǐ]

明

"bright" [míng]

8 single-graph characters and 8 combination-form characters are used.

(9) The test of reading pictographic characters, indicative characters, associative characters, and pictophonetic characters.

The purpose of this test is to find out whether special disorders exist corresponding to these different types of Chinese characters.

Examples of Pictographic characters are:

山

"mountain" [shān]

鱼

"fish" [yú]

田

"field" [tián]

Examples of indicative characters are:

上

"up" [shàng]

下

"down" [xià]

刃

"blade" [rèn]

Examples of Associative characters are:

人

"the mass" [zhòng]

歪

"askew" [wāi]

Examples of Pictophonetic characters are:

铃

"bell" [líng]

枝

"branch" [zhī]

10 pictographic characters, 10 indicative characters, 10 associative characters and 10 pictophonetic characters are used.

(10) The test of reading compound words.

The purpose of this test was to find out whether patients have special difficulty with compound words.

Examples of compound words are as follows:

火车
"train"

飞机
"aeroplane"

马虎
"careless"

12 compound words are used.

(11) The test of reading transliterated words.

Since the characters used in transliterated words do not have their Chinese meaning, and they are used just as symbols for representing the sound of foreign words, it is interesting to find out whether patients have special difficulty in reading these words.

Examples of transliterated words are as follows:

沙发

吉它

马拉松

"sofa" [shā-fā] "guitar" [gí-tā] "marathon" [mǎ-lā-sōng]

8 transliterated words are used.

(12) The test of reading onomatopoeic words.

Similar to transliterated words, onomatopoeic words do not have proper Chinese meaning, and they are purely used for sound representation. It is also interesting to find out whether patients have special difficulty with onomatopoeic words.

Examples of onomatopoeic words are as follows:

嗯	啦	扑通	轰隆
[ēn]	[lā]	[pū-tōng]	[hōng-lōng]

8 onomatopoeic words are used.

The final set is to examine the relevant other language functions of the dyslexic patients. The tests involved here are as follows:

(13) The Assessment of speaking ability.

The assessment is made on the basis of a patient's performance in repeating words and sentences, in voluntary speech and in conversation with the examiner.

(14) The assessment of listening ability.

The assessment is made by asking the patient to do something following instructions orally given by the examiner, such as pointing to objects in the room, or pointing to parts of the body.

(15) The assessment of writing ability.

The assessment is made by asking the patient to copy single words and sentences, to write his name and address and also to write anything he or she wishes.

(16) Other intelligence tests including calculation, formation of concepts, and anything else necessary.

4.3. CASE REPORTS

Because it is difficult to find brain damaged patients who are standard Chinese readers outside of Mainland China, this clinical study was carried out in Beijing. In conducting this study, letters were written, first of all, to two well known hospitals in Beijing (Beijing Tian-tan Hospital, and the First Hospital of Beijing Medical University) asking for suitable patients. After receiving some positive answers, I went back to China to do the research. I worked in Beijing for three months, and with the help of doctors from the two hospitals, I examined about 30 brain damaged patients, eleven of them were finally identified as having reading difficulties after having been brain damaged. Due to the limited time available for studying in Beijing, I was unable to examine more patients and find more significant symptoms in Chinese acquired dyslexia. I was also unable to go into more detail when examining patients with reading defects. There is a need for further study in these areas.

These eleven patients were found to have various acquired dyslexic symptoms. Apart from the reading ability, I also examined the other aspects of language function, i. e. listening, speaking and writing. The patients were found to have various degrees of language disfunction, and they were also found to have different connections between disorders in reading and impairment in other language functions. For the neuroanatomic features of these eleven patients, CT scans were obtained. In some special cases Single

Photon Emission Computed Tomography (SPECT), MR and Angiography were also obtained.

The basic conditions of these patients are as follows:

QXS, male, 64 years old, right handed. Han nationality. Native language: Mandarin. He used to be an engineer with a university degree. He suffered cerebral arteriosclerosis for years. Since mental symptoms such as bad memory had been become more and more severe, he went to hospital for treatment in 1987. The CT scan showed that the ventricles and sulci were enlarged. Meanwhile, SPECT (Single Photon Emission Computed Tomography) demonstrated CVBF decreased in the area of MCA in the left hemisphere. He was diagnosed as having encephalatrophy with more severe condition in the left hemisphere.

LWY, male, 53 years old, right handed. Han nationality. Native language: Mandarin. He was a cadre of a company with a secondary school education. In June of 1988, he suffered cerebral vascular occlusion in the left hemisphere. The CT scan showed that there was a low-density region in the conjunctive area of the temporal, parietal and occipital lobes. The lesion extended backwards to the pole of the occipital lobe.

LYM, male, 73 years old, right handed. Han nationality. Native language: Mandarin. Before retirement, he was a statistician. His also had a secondary school education. He suffered a meningioma in the left hemisphere. In 1986, he went to Beijing medical hospital to have the brain tumour removed. The CT

scan showed a 6 x 4 cm size tumour in the left temporal lobe.

LSH, male, 55 years old, right handed. Han nationality. Native language: Mandarin. He was a technician who had graduated from a polytechnic. In February of 1988, he suffered cerebrovascular occlusion in the left hemisphere. The CT scan showed a low-density area in the conjunctive area of the temporal, parietal and occipital lobes in the left hemisphere.

LQF, male, 76 years old, right handed. Han nationality. Native language: Mandarin. Before retirement, he was an accountant with a secondary school education. In 1986, he had cerebrovascular occlusion in the left hemisphere. The CT scan showed that around the left basal ganglia there was a low-density area. Outside of the left corona radiata there was a spot of occlusion.

LZY, male, 28 years old, right handed. Han nationality. Native language: Mandarin. He was a worker with a secondary school education. In January of 1988, he suffered cerebrovascular occlusion in the left hemisphere. The CT scan showed there was a lesion in the conjunctive area of the temporal, parietal and occipital lobes in the left hemisphere. Meanwhile, SPECT demonstrated CVBF had decreased in the area of the temporal and occipital lobes in the left hemisphere.

WBY, male, 58 years old, right handed. Han nationality. Native language: Mandarin. He is a professor in a university. In 1985, he suffered cerebrovascular occlusion in the left hemisphere. The CT scan showed some lesions located in the conjunctive area of the temporal, parietal and occipital lobes. At the time he was

examined in 1989, he had recovered a lot of his language ability.

LSJ, male, 65 years old, right handed. Han nationality. Native language: Mandarin. He used to be a secondary school teacher with a degree from a polytechnic. In 1988, he suffered a cerebrovascular occlusion in the left hemisphere. The CT scan showed there was a large low-density region on the junction of the temporal, parietal and occipital lobes.

LLH, male, 62 years old, right handed. Han nationality. Native language: Mandarin. He was a professor at a university. In 1986, when visiting Italy his brain was badly damaged in a car accident. The CT scan showed that there was a destruction on the left frontal and temporal part of the skull, and the cerebral cortex underneath had also been damaged.

LDJ, female, 57 years old, right handed. Han nationality. Native language: Mandarin. She was a secondary school teacher with a university degree. In June of 1988, she suffered cerebrovascular occlusion in the left hemisphere. The CT scan showed there were lesions in the left ganglia area and the left parietal and occipital area. Meanwhile, a MRT scan showed that there were lesions in the post-parietal branch and angular gyrus branch of CMA of the left hemisphere.

ZZG, male, 12 years old, right handed. Han nationality. Native language: Mandarin. He was a student at elementary school. He suffered from a kind of cerebral vascular malformation disease, called Moya Moya's disease. The CT scan made in August of 1988 showed that there was a lesion in the frontal lobe of the right

hemisphere. Meanwhile Angiography proved the diagnosis of Moya Moya's disease.

(The CT scans of these patients are in appendix C)

Table 4.1. Patient summary

Patients	Writing	Listening	Speaking	Hemisphere	Location
QXS	+	+	+	left	MCA area
LWY	-	+	+	left	temporal occipital
LYM	+	+	+	left	temporal
LSH	- -	+	+	left	parietal temporal occipital
LQF	- -	+	+ -	left	BG* area CR* area
LZY	+ -	+	+	left	parietal temporal occipital
WBY	+	+	+	left	parietal temporal occipital
LSJ	-	+ -	+	left	parietal temporal occipital
LLH	+	+	+	left	frontal temporal
LDJ	-	+	- -	left	parietal occipital
ZZG	- -	+	-	right	frontal parietal

BG: basal ganglia. CR: corona radiata.

The symbol '+' means normal; '+ -' means slightly impaired; '-' means impaired; '- -' means severely impaired.

The results in the table show that except for one case of a 12 year old boy (ZZG), all the other patients had their left hemisphere damaged. Within the left hemisphere the lesions were mostly localized in conjunctive areas of the temporal, parietal and occipital lobes.

On examining the relationship between the patients' listening, speaking, writing and reading disorders, several different connections were found. These patients can be put into 4 categories in the light of some of the neuroanatomical classifications of reading disorders that we reviewed in chapter 1.

(1) Pure alexia. This is a reading disorder which is not accompanied by writing impairment, that is, alexia without agraphia. The patients LYM, QXS, WBY and LLH suffered from this kind of acquired dyslexia. (2) Alexia with agraphia. This is the reading disorder which is accompanied by writing disorder. The patients LWY, LSH and LZY suffered from this kind of acquired dyslexia. (3) Alexia with agraphia and aphasia. This is the reading disorder which is accompanied not only by agraphia but also aphasia. The patients ZZG, LDJ and LQF had this kind of acquired dyslexia. (4) Alexia with aphasia, agraphia and listening problems. LSJ was such a patient. As we can see from the above, although all the patients had acquired dyslexia, the impairments to their listening comprehension, speaking ability and writing capacity were extremely varied, ranging from normal to very severely impaired.

4.4. RESULTS OF READING TESTS

Based on the results of several reading tests which were carried out individually on each of the 11 patients, a summary of reading disorders is represented in table 2. The table does not show the full results of the tests. Rather it is organized in such a way as to list the most significant results and also several types of reading errors (some results of the tests were not of any significance and are therefore not included in the table).

Table 4.2. Summary of reading tests

Patients	P	C	M	Reg	Sem	Ass	Com	Tra	Ono	No&Pse
QXS	22%	78%	33%	No	Yes	No	Yes	-a	--	+
LWY	89%	33%	78%	No	Yes	No	No	-a	--	-
LYM	44%	33%	89%	No	Yes	No	Yes	*	*	*
LSH	94%	94%	89%	Yes	Yes	Yes	No	+	-	-
LQF	33%	78%	78%	Yes	Yes	Yes	Yes	--	-	-
LZY	100%	100%	100%	Yes	Yes	No	No	+	-	-
WBY	100%	100%	100%	Yes	No	No	No	+	-	-
LSJ	29%	43%	57%	No	Yes	Yes	Yes	--	--	+
LLH	100%	100%	100%	No	Yes	No	No	-b	--	-
LDJ	*	57%	71%	No	Yes	*	*	*	--	--
ZZG	61%	30%	91%	No	Yes	*	*	*	--	*

In the first row of the table, "P" means naming pictures; "C" means naming characters; "M" means matching pictures with characters; "Reg" means regularization errors; "Sem" means semantic errors; "Ass" means problems with associative characters; "Com"

means problems with compound characters; "Tra" means reading transliteration words; "Ono" means reading onomatopoeic words; "No&Pse" means judgement of non-characters and pseudo-characters.

On the rest of the rows in the table, "*" means not examined, "No" means no such symptom. "Yes" means having such a symptom. The percentages in the table indicate the proportion of correct responses. In the column of judgement of Non-characters and Pseudo-characters, the symbol "-" means non-characters could be recognized but not pseudo-characters. In all other test columns, the same symbol "-" means impairment existed. While "--" means there was severe impairment. In the column of the test for reading transliterated words, "-a" means the patient could pronounce the words but could not understand them; while "--" means the patient could not pronounce the words and could not understand them either; "-b" means the patient could not pronounce the words but could understand the meaning of them.

In the table, there are many "-" in the column of the judgement of Non-characters and Pseudo-characters which indicate that most of the patients could recognize non-characters but failed to detect pseudo-characters. This implies the basic ability to recognize a Chinese character was intact.

In this summary of the results of tests done on Chinese reading disorders, the impairments of reading transliterated words and onomatopoeic words are revealed.

4.4.1. The routes in reading Chinese characters

(A). The route to sound

(i). The independent route from character to sound

There was a patient (QXS) who was found to be able to read aloud characters he was unable to match to pictures.

Table 4.3. Result of naming and matching test (QXS)

		P	C	M
房	house	+	+	+
球	ball	-	+	-
碟	plate	-	-	-
窗	window	-	+	-
门	door	+	+	+
旗	flag	-	+	-
壶	bettle	-	-	-
山	mountain	-	+	+
碗	bowl	-	+	-

Note: P stands for picture naming. C stands for character naming. M stands for matching picture with character. "-" stands for "failed". "+" stands for "accomplished".

From the table, we can see that QXS could pronounce 球 "ball" [qiú], 窗 "window" [chuāng], 旗 "flag" [qí], and 碗 "bowl" [wǎn] correctly, but, nevertheless he could not match them with corresponding pictures. This supports a route directly from character to pronunciation, and incidentally shows that matching these pictures is not just easier than naming.

The characters QXS failed to match with corresponding

pictures although he managed to pronounce them correctly, can be divided into two types, one type has a phonetic, such as 球 "ball", 旗 "flag" and 碗 "bowl"; the other type does not have a phonetic, and that is 窗 "window". The pronunciation of the first type of characters can be achieved by two possible routes: one is the route from the whole character to sound, the other is through the phonetic to sound. The pronunciation of the second type of character can only be made by the route from the whole character to sound. Therefore, the failure of matching these characters with the corresponding pictures, but success in pronouncing them, indicates that there might be two phonological routes which are independent of meaning. Although the route from the phonetic to sound is not demonstrated owing to the fact that there are two possible routes for reading the character with the phonetic, the route from whole character to sound is however demonstrated, because there is only one possibility for reading the character without the phonetic.

Interestingly, QXS was very poor at naming pictures, and with one single exception, the pictures he could name were the ones he could match. This indicates the role of retrieving the meaning - semantic specification - of a picture in naming. However, it leaves open the possibility that QXS had further deficit in object recognition. Perhaps he did not have the concepts of certain objects. He could not match pictures he had no conception of!

In the test of naming transliterated words, QXS was also found to have the reading deficiency of knowing the sound of some

characters without knowing their meanings. For example, he could pronounce the sound of 沙发 (means sofa) correctly, but could not define it. Thus, even if there were visual agnosia, there still seems to be a specific deficit of the route from character to meaning, which leaves the route from character to sound undisturbed.

(ii). Surface dyslexia and the sublexical route to sound

In alphabetic languages like English, studies have revealed that a kind of acquired dyslexia called surface dyslexia happens in some readers after brain damage (Patterson, et.al. 1985). The critical symptoms of surface dyslexia are: (1) regularization in pronunciation for irregular words, (2) preserved ability to read non-words, and sometimes (3) homophone confusion. Since Chinese characters are not alphabetic, they do not have a strict spelling to sound correspondence, the exclusive use of which is the essential reason for surface dyslexia. Therefore it has been debated as to whether surface dyslexic syndrome could exist in Chinese readers (Sasanuma,1985; M.Coltheart,1984). This is an important question since solving it will provide a cornerstone for further investigation of a universal reading process.

Does the surface dyslexic syndrome exist in Chinese readers? This study answers the question positively, but shows it has its special properties due to the characteristics of Chinese characters. Four patients are described who have difficulty with irregular characters, but who are able to read regular pseudo characters, unlike patients to be described later.

In this study, the surface dyslexic syndrome was found through testing the reading of regular, irregular, phonetic characters and pseudo-characters. The study also revealed that this surface dyslexic syndrome is in some ways quite different from what has been found in surface dyslexics in alphabetic language users. Therefore, this particular kind of surface dyslexic syndrome could be regarded as Chinese surface dyslexia. The materials used in revealing Chinese surface dyslexic syndrome included 12 phonetic characters, 40 regular characters, 21 irregular characters and 12 pseudo-characters. All of these characters (except pseudo-characters) are commonly used ones.

An example of regularization can be illustrated by the following:

Regular character

评

"comment"

[píng]

Irregular character

秤

"steelyard"

[chèng]

Phonetic radical

平

"level, flat"

[píng]

Regularization

秤

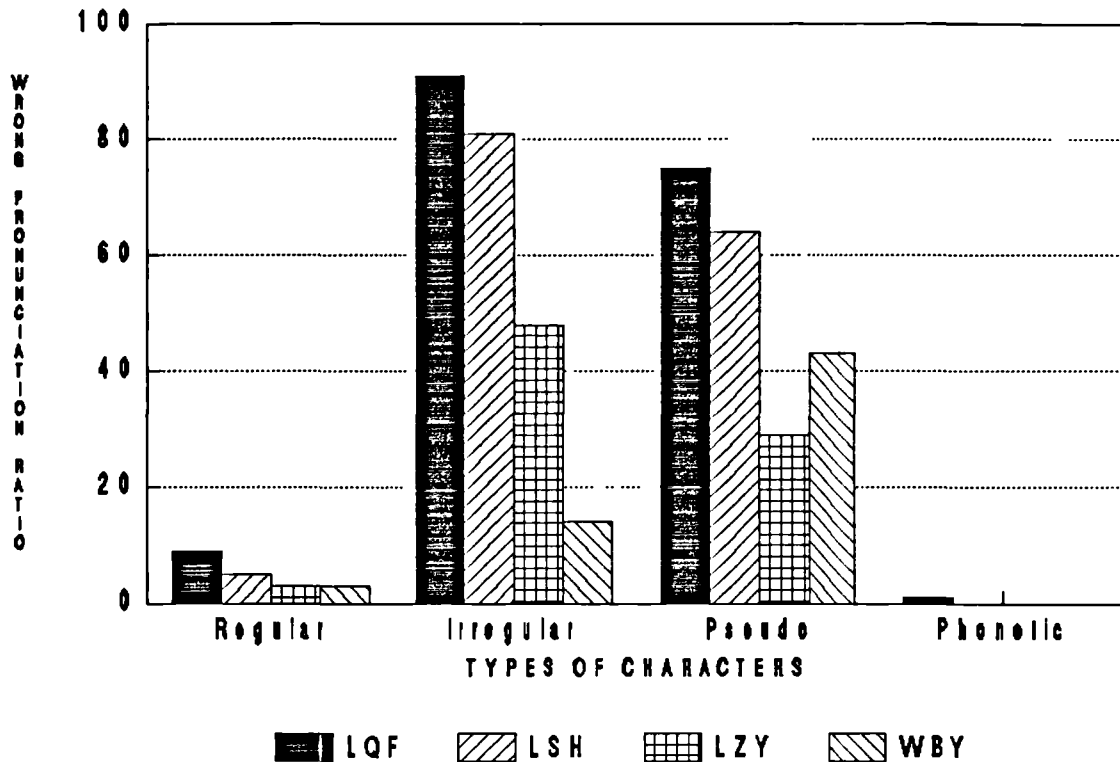
[chèng] _____ pronounced as [píng]

The patients LSH, LQF, LZY and WBY were found to make many more mistakes in pronouncing irregular characters than in pronouncing regular characters. The dominant type of mistake in pronouncing irregular characters was regularization. For instance, some of them pronounced the irregular character 埋 (which means bury, pronounced [mái]) as [lǐ] (which is the same sound of the component radical 里 "inside", pronounced [lǐ]). Thus characters with 里 as their phonetic can be pronounced [lǐ], such as: 理 "reason", 锂 "lithium", etc. Some of the patients pronounced the irregular character 秤 "steelyard", pronounced [chèng]) as [píng] which is the same sound of the component radical 平 "level". Again most characters with 平 as their phonetic are pronounced the same as the sound of 平 [píng], such as: 评 "comment", 坪 "level", etc.

In addition, when these patients met pseudo-characters with phonetic radicals, they tended to mistake these pseudo-characters for real characters by pronouncing their phonetics.

The results of the test of reading regular, irregular, phonetic characters and pseudo-characters are shown in figure 1.

FIGURE 4.1. SURFACE DYSLEXIA SYMPTOM



It is quite apparent, from the figure, that there is a great proportion of regularization errors made in reading irregular characters by the patients. Moreover, there are more errors made in reading irregular characters than those made in reading regular characters. To see if this has a significant meaning, a t-test is carried out, and the result shows that there is a significant difference between the number of errors made in reading irregular characters and the number of errors made in reading regular characters. t (regular with irregular) = 3.06, $P < 0.05$.

It is very important to note that even though the patients made many regularization errors in reading irregular characters, they never thereafter made errors of homophone confusion at all. Very often the patients understood precisely the meaning of the irregular characters in the reading of which they had just made regularization errors. It seems that the patients read the characters in one way, but got their meaning in another. For instance, having noticed the patient had made a regularization error in reading an irregular character -- 埋 ("bury", pronounced [mái]) had been read as [lǐ] (pronunciation of 里), I then asked the patient for the meaning of that irregular character. To my surprise, the patient gave me the correct meaning of that irregular character: 埋 meant bury. This shows that misunderstanding of irregular characters by confusion with regular pronunciation did not happen to the patient. Even in some cases where the patients did not know the precise meanings of the irregular characters on which they had made regularization errors, they were still quite clear about the difference between the irregular characters and the regular characters. For instance, when the patient failed to give the precise meaning of an irregular character, such as 秤, while he had made a regularization error by pronouncing it as [píng] (the correct pronunciation is [chèng]), he nevertheless could still tell me that the meaning of 秤 is different from 评, 坪 (评, 坪 which are regular characters, both pronounced as [píng]). Moreover, a further test was carried out by giving the surface dyslexic patients several

characters with the same sound, and when asked about the meanings of those characters, the patients, in some cases knew the precise meaning of each character, and in other cases, the patients knew how to differentiate between these characters even though they did not know their precise meanings. By and large, they did not make homophone confusions at all. This phenomenon is strongly contrary to alphabetic surface dyslexia in which homophone confusion is known to be one of the main characteristics. (J.C.Marshall, et al. 1973; M.Coltheart, 1981; M.Coltheart, et al. 1983). However, Howard & Franklin (1987) point out that some alphabetic surface dyslexics also do not use the sound they generate to determine meaning.

These patients give evidence of an indirect sublexical route to sound, that is independent of the routes via meaning and the direct route to sound. Indeed the lack of homophone confusion is further evidence of the independence of the sublexical route and the route to meaning.

Another important feature of Chinese surface dyslexia is that it is often accompanied by a key symptom of deep dyslexia. Three of the four patients who had surface dyslexic symptoms, i.e. LSH, LQF and LZY, made semantic errors when they were reading some Chinese characters. This is also a distinguishing aspect of Chinese surface dyslexia relating to the characteristics of the Chinese script.

(B) The route to meaning

(i) Independent route to meaning

A complementary symptom to that of QXS was observed in three patients, LYM, LWY, and ZZG. They were able to match characters correctly with the corresponding pictures even though they were unable to retrieve the name either from the character or the picture.

Take LYM as an example, the results of the naming and matching test are as follows (table 3).

Table 4.4. Result of naming and matching tests (LYM)

		P	C	M
锤	hammer	-	-	+
火	fire	-	-	-
风	wind	-	-	-
雨	rain	-	+	+
桶	bucket	-	-	+
星	star	+	+	+
钉	nail	-	-	+
骨	bone	-	+	+
锯	saw	+	-	+

Note: P stands for picture naming. C stands for character naming. M stands for matching picture with character. "-" stands for "failed". "+" stands for "accomplished".

From the table, we can see, patient LYM could not pronounce these characters: 锤 "hammer" [chuí], 桶 "bucket" [tǒng], 钉 "nail" [dīng] and 锯 "saw" [jù]. But he could match them correctly with corresponding pictures. This indicates that although the patient was unable to retrieve sound from these characters, he still understood their meaning.

LWY and ZZG had the same symptom. Table 5 and Table 6 represent the results of the naming and matching test given to them.

Table 4.5. Result of naming and matching tests (LWY)

		P	C	M
房	house	+	-	-
球	ball	-	-	+
碟	plate	-	-	+
窗	window	+	+	+
门	door	+	+	-
旗	flag	+	-	+
壶	kettle	-	-	+
山	mountain	+	+	+
碗	bowl	+	-	+

Table 4.6. Result of naming and matching tests (ZZG)

		P	C	M
房	house	-	-	+
球	ball	+	+	+
碟	plate	-	-	+
窗	window	+	+	+
门	door	+	+	+
旗	flag	-	-	+
壶	kettle	-	-	-
山	mountain	+	-	+
碗	bowl	+	+	+

These results suggest that matching can be achieved without reference to the word's sound, and hence supports a route to meaning not mediated by phonology. Notice that both picture and character naming are impaired in these patients, though the items showing the deficit are largely non-overlapping. There thus seems to be item-specific deficits, though neither predicts matching performance.

(ii) Deep dyslexic symptoms

Deep dyslexia is another kind of acquired dyslexia found in alphabetic language users (Coltheart, et.al. 1980). The distinguishing feature of deep dyslexia is that the patients make many semantic errors when reading a list of words. They quite often cannot pronounce the target words correctly when they are asked to read; instead, they read out some other words which have a semantic relationship with the target words. For example, "city" read as "town", "bush" read as "tree" (Kapur and Perl, 1978; Patterson and Marcel, 1977). Quite naturally, a question arises as to whether or not the deep dyslexic symptoms also exist in Chinese reading disorders, and if so, whether or not Chinese deep dyslexic symptoms have any special features due to the characteristics of Chinese characters. This study gave a positive answer to this question. Deep dyslexic symptoms do exist in Chinese reading disorders, and there are some special features of Chinese deep dyslexic symptoms.

In this study it has been discovered that Chinese patients

also made semantic errors when they were reading Chinese characters which are just like the deep dyslexic patients of alphabetic language users. Some examples of semantic errors are as follows: reading 犬 (means dog, pronounced [quǎn]) as 猫 (means cat, pronounced [māo]); reading 子 (means child, pronounced as [zǐ]) as 小 (means little, pronounced [xiǎo]). These semantic errors were revealed in several tests, such as: in the test of naming pictures and characters and matching them together, in the test of reading single and compound characters, in the test of reading regular, irregular, phonetic characters and pseudo-characters, and in the test of semantic categorizing.

One fact concerning Chinese deep dyslexic symptoms should be brought to our attention and that is that semantic errors in reading Chinese characters were found to be common in the reading behaviour of Chinese patients. Firstly, when all of the 11 acquired dyslexic patients were examined, 10 made semantic errors in reading tests. There was only one exception, which was the patient WBY, and this patient had nevertheless some clinical reason for this exception: he had a stroke in 1985, three years before the examination date, and his language abilities including his reading capacity had since recovered a lot. Secondly, there seems to be no strict anatomic reason for Chinese deep dyslexic symptom holders, because not all of the patients who have deep dyslexic symptoms fit the requirement that there be severe damage in the left hemisphere (M.Coltheart, 1980). What has been found in Chinese patients who had deep dyslexic symptoms is that in some of the patients, such as

LYM, LSJ, and LLH, a large part of their left hemisphere was damaged; but other patients did not have damaged areas as extensive as those which were found in alphabetic language users. This generality of semantic errors in reading Chinese characters could be regarded as a special feature of Chinese reading disorders, and this is different from what happens in alphabetic language users and it may relate to the characteristics of the Chinese script.

In connection with the generality of Chinese deep dyslexic symptoms, another feature of Chinese deep dyslexia which naturally appears is that the Chinese deep dyslexic symptoms can be accompanied by the symptoms of other reading disorders. These accompanying symptoms are: surface dyslexic symptoms, associative dyslexic symptoms and compound dyslexic symptoms. This feature is also quite different from the deep dyslexia of alphabetic language users.

The following are examples of semantic errors made by patients when they were reading Chinese characters.

犬 _____ "dog" [quǎn]	猫 _____ "cat" [māo]
象 _____ "elephant" [xiàng]	马 _____ "horse" [mǎ]
耳 _____ "ear" [ěr]	手 _____ "hand" [shǒu]
子 _____ "child" [zǐ]	小 _____ "little" [xiǎo]

别	_____	分
"leave" [bié]		"separate" [fēn]
恨	_____	仇
"hate" [hèn]		"enemy" [chóu]

4.4.2. Analysis of the deep dyslexic symptom -- semantic errors

(A). The relation between semantic errors and significs

As we have seen from the analysis of Chinese characters, there are many Chinese characters which contain a signific as one of their components. This signific has the function of indicating or implying the category of meaning which the character stands for. Therefore a question is raised here: do the semantic errors made by patients have some relationships with the significs of the characters they read?

It is found that most semantic errors happen with the single-graph characters which have not got a signific in their construction (75 per cent of all characters which produce semantic errors are single-graph characters). However, 62 per cent of all the characters which have a signific in the structure produce semantic errors. On the whole, there are only 12 per cent of all semantic errors which have a relationship to the signific of the characters. Some examples of the relationship between semantic errors and significs are as follows: 秧 "seedling", [yāng], was read as 苗 "young plant", [miáo]. 禾 is a signific which indicates something relevant to grain, especially rice. The meaning of 禾 is grain. It's pronunciation is [hé]. 躯 "trunk",

[qū], was read as 体 "body", [tǐ]. 身 is a signific which indicates something relevant to a body. The meaning of 身 is human body. It's pronunciation is [shēn]. 锯 "saw", [jù] was read as 锤 "hammer", [chuí]. 钅 is a signific which indicates something is made from metal. 钅 is no longer a single-graph character as many significs are. 钅 is evolved from a single-graph character 金 [jīn] which means "gold" or "metal".

(B). Types of semantic errors

Since semantic errors have been observed in the normal adult fast reading experiment, it is interesting to compare the errors made in normal adults and the errors made by neurological patients. In normal adult fast reading experiment, I have made an analysis of the semantic errors found there. The results show that the relationship between the semantic errors and the characters being read seem to fall generally into two categories. The first category includes the errors which share some same semantic features with the stimuli. In this category there are four types: (1) the accompanied synonym: the errors and stimuli are very often used together, whilst each word has the same or similar meaning, such as: 想 "think" [xiǎng] -- 思 "think" [sī], usually used as 思想 "thought". (2) synonym: the errors and stimuli can be used in the same semantic situation but usually appear alone, such as: 巢 "nest" [cháo] -- 穴 "nest" [xué]. (3) similar words but not exact synonyms, such as: 护 "protect" [hù] -- 防 "prevent" [fáng]. (4) the relation words: the errors and stimuli can be

linked together with movements of a similar nature, like 握 "hold" [wò] -- 抓 "grasp" [zhuā], 护 "protect" [hù] -- 搂 "hug" [lǒu] ; or in the domain of similar things such as: 鲸 "whale" [jīng] -- 鱼 "fish" [yú], 唇 "lip" [chún] -- 舌 "tongue" [shé]. The second category includes the semantic errors which did not share the same semantic feature with stimuli, but they were linked by associative relations. They could be associated in terms of cause and result such as: 焰 "flame" [yán] -- 火 "fire" [huǒ], 翻 "jump" [fān] -- 欢 "joy" [huān], or associated in terms of related properties such as: 绳 "rope" [shéng] -- 长 "long" [cháng].

In the cases of Chinese neurological patients, what do the different kinds of relationships between semantic errors and characters being read look like? Do they fall into the same or similar categories and types as those in experiments with normal subjects? I conducted an analysis of the semantic errors made by these Chinese neurological patients, and got a positive answer to the question. Moreover, apart from the similarities between the error types made by normal subjects and those made by neurological patients, there were also some detailed differences among these two groups.

The semantic errors made by neurological patients can also be divided into two general categories similar to that in normal subjects: One category includes the errors which shared some of the same semantic features with the stimuli. The other category includes the errors which did not share the same semantic features

with the stimuli but they were linked associatively by some related features. In the first category we can find some of the same types as that in normal readers: (1) some semantic errors fall into the type of accompanied synonym, such as: 恨 "hate" [hèn] read as 仇 "hate" [chóu], 恨 and 仇 are usually used together as 仇恨 "enmity"; 别 "separate" [bié] read as 分 "divide" [fēn], 别 and 分 are usually used together as 分别 "leave each other"; 躯 "trunk" [qū] read as 体 "body" [tǐ], 躯 and 体 are usually used together as 躯体 "body". (2) Some semantic errors are synonyms, such as: 犬 "dog" [quǎn] read as 狗 "dog" [gǒu]; 足 "foot" [zú] read as 脚 "foot" [jiǎo]; 甘 "sweet" [gān] read as 甜 "sweet" [tián]; 卒 "warrior" [zú] read as 兵 "soldier" [bīng]. Different from the above accompanied synonyms which always appear together, these synonyms usually do not appear together. (3) Some semantic errors fall into the type of semantically similar words but are not exact synonyms, such as: 帚 "broom" [zhòu] read as 刷 "brush" [shuā]; 房 "house" [fáng] read as 屋 "room" [wū]; 岭 "ridge" [lǐng] read as 山 "mountain" [shān]. (4) Some semantic errors fall into the type of relation words. There is a similar link among the relation words to that in normal subjects. That is the link which connects similar things within the same domain, such as: 花 "flower" [huā] read as 树 "tree" [shù]; 锯 "saw" [jù] read as 锤 "hammer" [chuí].

In the second category in which semantic errors did not share the same semantic features with stimuli, I failed to find the same

kinds of errors as in normal readers. One kind of error in this category was a kind of noun-verb association, such as: 马 "horse" [mǎ] read as 跑 "run" [pǎo]; 鸟 "bird" [niǎo] read as 飞 "fly" [fēi]; 风 "wind" [fēng] read as 刮 "blow" [guā]; 弓 "bow" [gōng] read as 射 "shoot" [shè]; 水 "water" [shuǐ] read as 喝 "drink" [hē]. Moreover, there was a kind of semantic error made by neurological patients which was associated with stimuli in a kind of verb-preposition relation, such as: 还 "return" [huán] read as 从 "from" [cóng]; 返 "back" [fǎn] read as 往 "for" [wǎng]. In addition to these, there were also other kinds of associations between semantic errors and stimuli found in neurological patients which were not found in normal Chinese readers. Such as: 子 "son" [zǐ] read as 小 "little" [xiǎo]; 凸 "protrude" [tū] read as 曲 "curvy" [qū]; 明 "bright" [míng] read as 看 "see" [kàn]; 胖 "fat" [pàng] read as 肿 "swollen" [zhǒng].

4.4.3. A vocabulary analysis of a deep dyslexic patient

There was a case of deep dyslexia which provided a unique opportunity for us to see more details of his reading problems by examining his vocabulary. Patient LSJ was quite an active learner. When he left hospital, he did not rest passively waiting for recovery, rather he adopted an active strategy to help his recovery by learning. He spent much of his time at home reading a dictionary (Xin Hua Zi Dian, 1971) to see how many characters he

failed to read, and how many characters he still retained the ability to read. An entire dictionary had been read through by him. Each character in every page of that dictionary was marked by him according to his reading results. The marks he used include circles, ticks and underlinings. The circles were of two types, one was red, the other was black. The former was used to indicate the characters which he could still correctly read, i.e. he knew both the meaning and the sound of them; the latter was used to indicate the characters which he felt looked strange. The ticks were used to stand for the characters for which he knew the meaning (either precisely or roughly) but failed to get their pronunciations; the underlinings were used to signify the characters which he did not know at all, i.e. he could not tell either the meaning or the pronunciation of them.

The dictionary (Xin Hua Zi Dian, 1971) LSJ used is the same as that I used for my statistical analysis of the phonetic representation of Chinese characters. As I have mentioned before, this dictionary has a vocabulary of about 11,000 characters. There were 490 characters which were marked by LSJ in red circles. This meant that he knew 490 characters both by meaning and pronunciation. There were 103 characters which were marked by black circles, which to LSJ looked strange as to their status as Chinese characters. There were 5,570 characters which were marked by ticks. This meant that there were 5,570 characters which LSJ failed to pronounce but he still, somehow, knew their meaning to some extent. Apparently, LSJ retained in his vocabulary 6,060

characters whose meaning he still knew (though not all precisely). Thus, only for 8 % of his total reading vocabulary could LSJ get the correct pronunciation ($490 / 6060 = 0.08$). This showed that his ability of knowing the sound of characters was quite limited.

By analysing LSJ's reading performance through the data from the dictionary, two interesting phenomena were found.

First, there was a kind of double dissociation in LSJ's reading performance. LSJ could read some characters which were combination-forms, but he failed to read those characters which were single-graphs even though those single-graphs were used in combination-forms which he could successfully pronounce, and moreover, the pronunciation of those single-graphs and combination-forms were the same. On the other hand, LSJ could read many characters which were single-graph, but he failed to read those characters which were combination-form, despite their having the same pronunciation. This double dissociation demonstrated that LSJ always read characters on the basis of seeing the character as one whole and he could not use the phonetics in his attempt to pronounce characters which are combination-forms. Moreover, further analysis shows there were many more cases which fell into the second type than those falling into the first type. That is, there were more circumstances where LSJ could read single-graph but failed to read the combination-form (No.= 82) than those where he could read combination-form but failed to read the single-graph (No.=18).

Secondly, there were frequency and complexity effects on

LSJ's reading performances. A statistical comparison was made between a sample of 100 characters from the characters with a red circle and a sample of 100 characters from the characters with a tick. The results were: The mean for the frequency values of characters with a red circle was 0.04025, while the mean for the frequency values of characters with a tick was 0.00562. The difference between them was quite significant, $t = 4.34$, $P < 0.001$ (two tailed). The mean for the numbers of strokes of characters with a red circle was 8.010, while the mean for the numbers of strokes of characters with a tick was 11.020. The difference between them was quite significant, $t = 5.93$, $P < 0.001$ (two tailed). These statistics revealed that LSJ had a better ability to read comparatively frequent and simple characters than to read comparatively less frequent and complex characters.

Moreover, consistent with these frequency and complexity effects, there was a discrepancy in LSJ's ability to read two kinds of numbers. There are two kinds of Chinese characters for numbers. They differ in the complexity of their structure. One is simple, another is complex. The simple ones are: 一 "one", 二 "two", 三 "three", 四 "four", 五 "five", 六 "six", 七 "seven", 八 "eight", 九 "nine", 十 "ten". The complex ones are: 壹 "one", 貳 "two", 叁 "three", 肆 "four", 伍 "five", 陆 "six", 柒 "seven", 捌 "eight", 玖 "nine", 拾 "ten". The average number of strokes for simple ones is about 3, while the average number of strokes for complex ones is about 9. Moreover, the simple ones are used more often than complex ones (due to the

lack of actual frequency counts for complex ones, the statistics for such comparison can not be made now). LSJ had a much better capacity for reading the simple characters of numbers than that for reading the complex characters of numbers. He could read out correctly all the simple characters of numbers except 五 "five" and 七 "seven" for which he knew the meaning but failed to pronounce. By contrast, he could not pronounce the complex characters of numbers at all although he knew the meanings of all of them except 玖 "nine" which he failed to recognize. This, again, seems to indicate that the ability to read simple and more frequent characters are better preserved than that of reading complex and less frequent characters.

4.4.4. Comparison between surface and deep dyslexic patients

Of all these 11 Chinese acquired dyslexic patients, 10 were found to make semantic errors, one of the key symptoms of deep dyslexia, and 4 were found to have regularization errors, one of the key surface dyslexic symptoms. Given that normal people also make semantic errors, it might be reasonable to categorize these patients as suffering from two kinds of acquired dyslexia judging by whether or not they make regularization errors; those who do will be classified as surface dyslexic patients and those who do not will be classified as deep dyslexic patients. After this categorizing, we will be able to make comparisons between the two kinds.

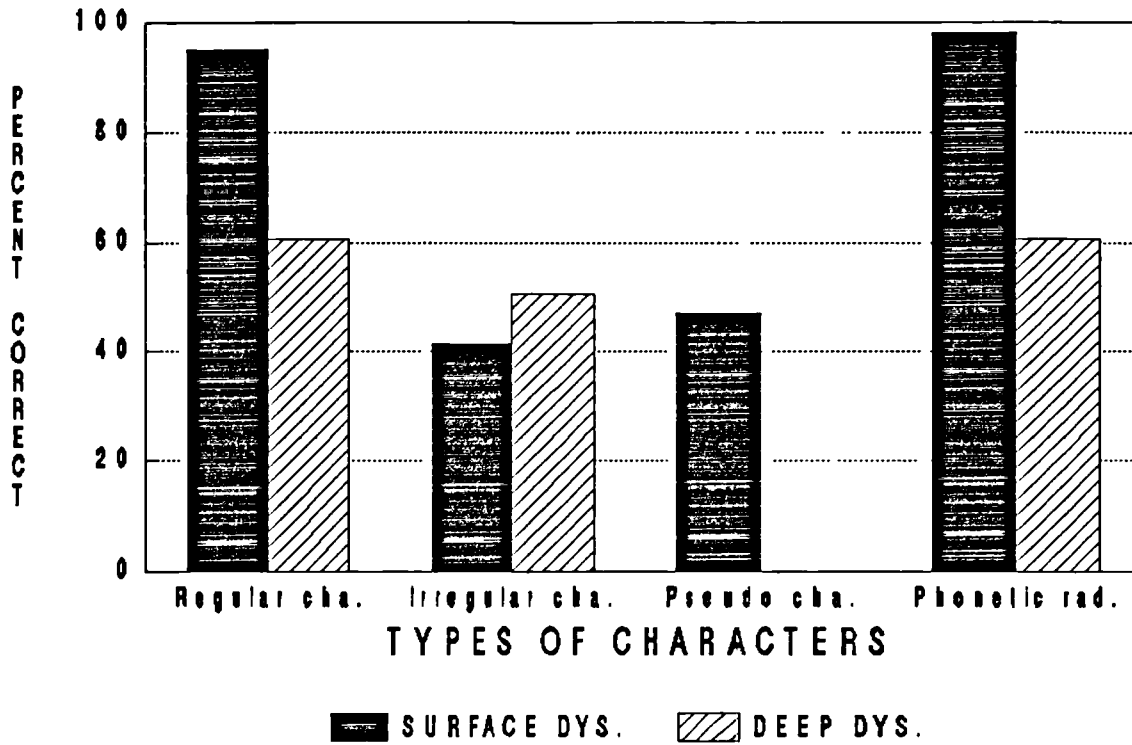
(a) Comparisons in reading regular, irregular, pseudo characters and phonetic radicals by deep and surface dyslexic patients.

Table 4.7. Single word reading of deep and surface dyslexic patients

Types	Patients	Regular	Irregular	Pseudo	Phonetic
Deep Dyslexia	QXS	57 %	67 %	0	100 %
	LWY	50 %	37 %	0	42 %
	LYM	58 %	40 %	0	58 %
	LSJ	50 %	33 %	0	42 %
	LLH	100 %	100 %	0	100 %
	LDJ	60 %	37 %	0	33 %
	ZZG	50 %	40 %	0	50 %
Surface Dyslexia	LSH	95 %	19 %	36 %	100 %
	LQF	91 %	9 %	25 %	92 %
	LZY	97 %	52 %	71 %	100 %
	WBY	97 %	86 %	57 %	100 %

The numbers shown in the table are the percentage of correct responses.

FIGURE 4.2 SINGLE WORD READING



From the table and the figure, the following differences are evident: (1). All deep dyslexic patients were completely unable to read pseudocharacters aloud whereas the surface dyslexic patients were on average able to read better than 40 % of them. (2). Deep dyslexic patients showed comparable performance on regular and irregular characters, $t = 0.88$, $p > 0.5$ (two tailed). Whereas the surface dyslexic patients were significantly better on regular characters, $t = 3.06$, $p < .05$ (two tailed). (3). Correlations

between patients' reading radicals and reading other characters shows that reading radicals helps with the reading of regular characters for surface dyslexic patients, $r = .94$, $p < .027$. Whereas this does not help deep dyslexic patients, $r = .65$, $p > .06$. However, surface dyslexic patients are not helped in the reading of irregular characters, $r = .62$, $p > .20$. Therefore, this effect does not simply reflect better reading abilities for all kinds of characters.

(b) Comparison in semantic ratio and regularization ratio between deep and surface dyslexic patients

Table 4.8. Deep and Surface dyslexic patients' semantic error and regularization ratio

Types	Patients	Semantic error ratio	Regularization ratio
Deep Dyslexia	QXS	24 %	0
	LYM	45 %	0
	LLH	54 %	0
	ZZG	57 %	0
	LDJ	50 %	0
	LWY	47 %	0
	LSJ	41 %	0
	LSH	17 %	46 %
Surface Dyslexia	LZY	21 %	53 %
	LQF	14 %	25 %
	WBY	0	75 %

Semantic error ratio = No.Semantic errors / No.errors.

Regularization ratio = No.Regularization errors / No.errors.

From the table, two obvious contrasts are evident: 1. Deep dyslexic patients made no regularisation errors, whereas the surface dyslexic patients made a high proportion of regularisation errors. 2. Both deep and surface dyslexic patients made semantic errors, but the semantic error ratio was obviously different.

The statistic of the difference of semantic error ratio between deep and surface dyslexic patients reveals that a significantly higher ratio was made by deep dyslexic patients: $t = 5.28$, $p < .0001$ (two tailed).

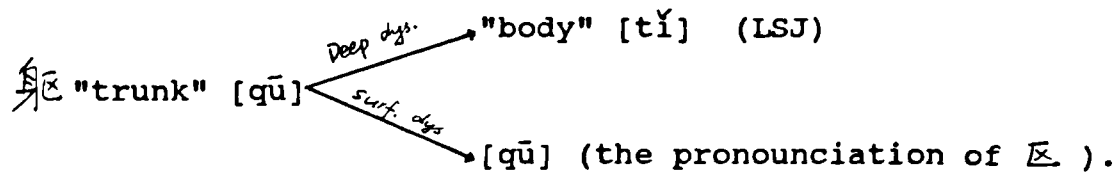
(c) Overall comparison between surface and deep dyslexic patients

In both alphabetic and Chinese readers, deep and surface dyslexic patients have been found to have the following differences:

Deep dyslexic patients	Surface dyslexic patients
1. Many semantic errors	1. No or few semantic errors
2. No regularisation errors	2. Many regularisation errors
3. Comparable accuracy for regular and irregular characters	3. Regular characters read more accurately
4. Pseudo-words unreadable	4. Pseudo-words readable

In addition, in surface dyslexic patients, semantic errors only happen when the characters being read have no phonetic. While,

in deep dyslexic patients, semantic errors happen no matter whether the characters have a phonetic or not. For example:



There were 17 percent semantic errors made by deep dyslexic patients which had a phonetic.

4.4.5. Script specific features in reading process: some characteristics of reading Chinese characters

(A) Symptoms characterised by reading associative characters

Due to the characteristic of Chinese characters, Chinese acquired dyslexic patients have some special symptoms. One type is the Associative dyslexic symptom.

As we have seen, Chinese characters can be classified into several types, and one of these types is associative characters. The associative dyslexic symptom is a kind of reading disorder which happens when the patients read associative characters.

Associative characters consist of two or more radicals. The characteristic of this type of character is that the whole meaning of the character can be derived by associating the meaning of the individual radicals. To be more precise, associative characters can be further divided into two sub-types. One that has different radicals as its components, another that has the same radicals as its components.

An example of the first type of associative character is 𠂇

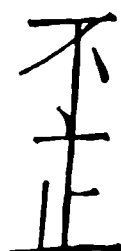
, which means askew, pronounced [wāi]. It consists of two different radicals. One of them, 丌, means not, pronounced [bù]; another, 正, means straight, pronounced [zhèng]. It is quite clear that the whole meaning of 歪, askew, is a logical synthesis of the meanings of the individual radicals, 丌 "not" and 正 "straight".

An example of the second type of associative character is 众, which means the masses, pronounced [zhòng]. It consists of three radicals which are the same, 人, 人, 人. 人 means person, pronounced [rén]. It is also clear that the whole meaning of 众, the masses, could be derived by a concrete association between the components of the character.

In my study, some patients were found to have a special reading symptom when they were reading the above two types of associative characters: They could pronounce the individual radicals of the characters correctly, and knew the meaning of these individual radicals as well. But they could not pronounce the whole characters. Nevertheless, they could get the meaning of the characters correctly. There seems to be no obvious difference between reading associative characters with different components and reading associative characters with the same components. That is, the same thing happened when associative dyslexic patients were reading associative characters, regardless of which type of associative characters they were reading.

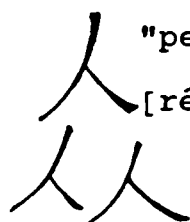
LSH, LQF and LSJ were found to have this kind of reading disorder. Examples of their reading are as follows:

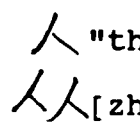
(1) Reading associative characters with different components.

	"no" _____	understood correctly
	[bù] _____	pronounced correctly
	"straight" _____	understood correctly
	[zhèng] _____	pronounced correctly

	"askew" _____	understood correctly
	[wāi] _____	failed to pronounce it

(2) Reading associative characters with same components.

	"person" _____	understood correctly
	[rén] _____	pronounced correctly

	"the mass" _____	understood correctly
	[zhòng] _____	failed to pronounce it

(B) Reading compound characters

As we have seen from the analysis of Chinese characters, one of their distinguishing features is that they do not always

represent words. In fact, the linguistic nature of Chinese characters should be regarded as the representation of morphemes. Although in many cases a Chinese character on its own can be a word, the majority of Chinese words in common use are constructed from two or more characters. The words constructed by two or more characters could be called compound words. Thus we can distinguish them from single character words. However, the characters used in compound words (as their morphemes) could also be words when they are used alone in many cases. For example, 马 is a character and also a word, which means horse, pronounced [mǎ]. 虎 is a character and also a word, which means tiger, pronounced [hǔ]. Whereas when 马 and 虎 are put together, they become a compound word 马虎 which means careless and this word is an entirely different word from 马 and 虎. Compound dyslexic symptom is a kind of reading disorder which happens when the patients read compound words.

QXS, LYM, LQF and LSJ were found to have difficulties when they were reading compound words. They could pronounce the characters which were used as the components of compound words correctly, and understand these characters' meanings correctly as well, but they failed to understand the meaning of the compound words. For instance, some of them could pronounce 马 and 虎 correctly, and understand that 马 means horse and 虎 means tiger precisely, but they failed to access the meaning of 马虎 together, which is careless. That is, they could not understand the meaning of 马虎 in which 马 and 虎 being put together as a

whole compound word. In some cases, they did not even know that the characters used in compound words could be put together to form a compound word. The patient, LSJ, even thought that 马 and 虎 should not be put together because 虎 would eat 马. Some patients thought that when 马 and 虎 were put together, they did not make any sense. They thought it had no meaning at all and didn't regard it as a compound word.

An important aspect of this compound dyslexic symptom is that the patient did not show the compound dyslexic syndrome for all compound words used in the test, rather, they were found to have a strict selectivity in showing symptom for different kinds of compound words. The details of this selectivity are as follows:

(1) There is a kind of compound word which could be regarded as a logical compound word. The meanings of the characters used in this kind of compound word have an obviously logical relationship with the meaning of the compound words. That is, the meaning of the compound word can be derived logically from the meanings of its component characters. An example of this kind of compound words is like 飞机, where 飞 means fly, 机 means machine, while 飞 and 机 together as a compound word 飞机 means aeroplane.

The patients did not show the compound dyslexic syndrome when they were reading the logical compound words like the above. QXS could read all of the individual characters and understand all of these compound words. LQF, LYM and LSJ could read individual characters in 5 compound words and understand them as well.

(2) There is another kind of compound word which could be regarded as a metaphorical compound word. The meanings of the characters used in this kind of compound word have no obviously logical relationship with the meaning of the compound word. That is, the meaning of the compound word can not be derived logically from the meanings of its component characters. The relationship between the meaning of the compound word and the meaning of its component characters is quite abstruse. An example of this kind of compound word is 马虎. Superficially, 马虎, careless, has no relationship with horse and tiger. The relationship between the compound word 马虎 and its component characters 马 and 虎 is quite abstruse. What we know about the story of this compound word is that 马 and 虎 used together to mean careless, was in the well-known novel "孽海花" written hundreds years ago to describe some people's carelessness when dealing with an important matter.

The patient showed the compound dyslexic symptom when they were reading this kind of compound word.

Examples of the compound dyslexic symptom are as follows:

火 车

 ✓ ✓

"train"

 火 车

 "fire" "vehicle"

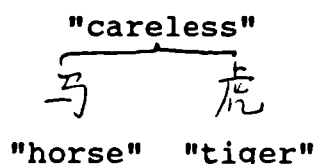
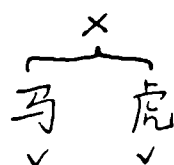
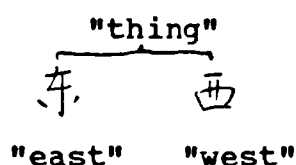
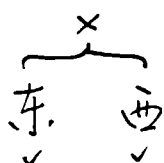
飞 机

 ✓ ✓

"aeroplane"

 飞 机

 "fly" "machine"



In the example, " ✓ " indicates that the patients could pronounce and understand as well; "x" indicates that the patients failed to understand. 6 such kind of compound words were used in the test. QXS failed to understand 4 compound words while he could read all the individual characters of all the compound words. LYM could read individual characters in 5 compound words but failed to understand 3 compound words. LQF could read individual characters in 4 compound words, but failed to understand 2 compound words. LSJ could read individual characters in 5 compound words but failed to understand 3 compound words.

4.5. DISCUSSION

The above research on Chinese acquired dyslexia threw some light on the nature of the processes of reading. With respect to the multi-route reading model, we can see the similarity between the process of reading alphabetic words and the process of reading

Chinese characters. That is, the process of reading Chinese characters is the same as that of reading alphabetic words in the sense that they both have a multi-route procedure. As far as the individual routes are concerned, this clinical study provide evidence for three routes in reading Chinese characters which are compatible with those in reading alphabetic words. These three routes are: 1) the route from the whole character to sound; 2) the route from the phonetic to sound; 3) the route from character to meaning without sound.

The question whether or not these routes are independent of each other can be answered by examining whether or not there is dissociation among these routes. In this respect, we have found evidence that there is a separability between the route from the character's form to its sound and the route from the character's form to its meaning. In other words, the connections between the character's form, sound and meaning can be selectively blocked as the results of brain damage. In this respect, we have actually found two kinds of reading disorders in terms of selectively blocking the connection between the character's form, sound and meaning. One is the reading disorder manifested in a blockage between the form and the meaning; the other is the reading disorder manifested in a blockage between the form and the sound. Patient QXS can be called a case of the first type. Patients LYM, LWY, and ZZG can be called cases of the second type.

The existence of these two types of blockages demonstrates that there must be at least two routes in reading Chinese

characters which are independent. One is the route directly from a character's form to its meaning, another is the route directly from a character's form to its sound. However, we have shown that the processes leading from a character's form to its sound can actually be performed by two routes, one is from the whole character to sound, and the other is from the phonetic to sound. In the case of QXS, the route from the whole character to sound has been demonstrated to be independently used. As for the route from the phonetic to sound, the existence of surface dyslexia has shown that this route is also independently used by some patients.

Thus, in this respect, the process of reading Chinese characters is compatible with the dominant cognitive neuropsychological reading model derived from reading alphabetic languages. Therefore, as far as the heated question about the role of phonological recoding in reading Chinese characters is concerned, the existence of the form-meaning dyslexic and form-sound dyslexic symptoms can be taken as a demonstration that phonological recoding is parallel and independent.

As far as the routes in reading Chinese characters are concerned, we need to direct our attention to a very important fact found in this study, that is: compatible with some types of acquired dyslexia in reading alphabetic languages, there also exists analogues of surface dyslexia and deep dyslexia symptoms in reading Chinese although these symptoms in Chinese possess some special qualities. Studies on Japanese acquired dyslexia seem to indicate that there is not a surface dyslexia in reading Kanji

(Sasanuma, 1985), whereas surface dyslexic syndrome appears in reading Chinese characters. This seems to be contradictory if we regard the processes of reading Chinese characters and reading Japanese Kanji as exactly the same. However, we should take into consideration that Kanji characters are quite different from Chinese characters as I have shown previously. The fact that two pronunciations coexist for a same Kanji character must have an important effect on the reading process and this will in turn make a big difference between reading Kanji and reading Chinese characters. Since "Kun" pronunciation has no relationship with phonetics in the Kanji characters, and there is uncertainty with "On" readings when following the phonetics, the phonological route in reading Kanji could therefore fail to work practically. This could be an explanation for why there is no surface dyslexia in reading Kanji.

The existence of the Chinese surface dyslexic syndrome indicates the role of the phonetic in representing the character's sound. In Chapter 2 I made an analysis of the phonological representation system of Chinese characters. We know that Chinese characters do have a way of expressing their sound which is via phonetics in pictophonetic characters. Further analysis also reveals the power of representing sound by phonetics. We have got the actual figures for this representation. The ratio of representing sound completely by phonetics, i.e. CRP, is 36 %, the ratio of partial representing sound by phonetics, i.e. PRP, is 48 %, the ratio of not representing by phonetics, i.e. NRP, is 16 %.

Obviously, 36 percent complete representation ratio and 48 % partial representation ratio can give a basis for the existence of regularization errors when the patients were reading irregular characters. This demonstrates a phonological route in reading Chinese characters which is compatible with the sublexical route in the multi-route model.

The existence of Chinese deep dyslexia emphasises the use of a non-phonological route in reading Chinese characters. Recalling that in the experiment with normal Chinese subjects we have found some semantic errors in the speeded reading condition, there seems to be a consistency with what we have found in the clinical field. Chinese characters, as a logographic system, logically allow readers to read Chinese characters via a non-phonological route. Further analysis of the vocabulary of a deep dyslexic patient (LSJ) uncovers a double dissociation between reading single-graph and reading combination-form which demonstrates that the patient always reads characters on the basis of the whole character while he could not use the phonetics in his attempt to pronounce characters which are combination-form.

Moreover, the comparison between Chinese surface and deep dyslexia reveals more similarities with those in alphabetic readers. The differences between surface and deep dyslexia in reading non-characters, in reading irregular characters, and in the semantic error ratio, show an analogy to alphabetic readers. This analogy gives us a stronger rationale for different routes being used in surface and deep dyslexia of Chinese readers.

Apart from the similarities between Chinese surface/deep dyslexia and that in alphabetic readers, there also exist some differences between them, and these differences should be taken into account when we talk about the routes used in reading Chinese characters and the universality of the processes of reading.

In Chinese surface dyslexia, the criterion I used for diagnosis is the regularization of pronunciation in reading irregular characters. It has been noticed particularly that Chinese surface dyslexic symptoms are not accompanied by homophone confusion, but, they are often accompanied by semantic errors. These special features imply that the underlying mechanism of the Chinese surface dyslexic syndrome is different from that of alphabetic surface dyslexia. Surface dyslexia in alphabetic language, according to the multi-route model, is caused by some damage in the lexical route while the non-lexical route remains intact, thus, reading has to go through the non-lexical route, in which a Grapheme-Phoneme Conversion (GPC) process operates. Whereas in reading Chinese characters, there is no precise equivalent of GPC in the reading process. Instead, a phonetic (the phonetic in pictophonetic characters)-Syllable Conversion (PSC) can be regarded as a counter part to GPC. By going through this PSC, pronunciation in reading Chinese irregular characters is regularized by Chinese surface dyslexic patients. However, the fact that this regularization in the pronunciation of irregular characters is not accompanied by homophone confusion, but is accompanied by deep dyslexic symptoms, which clearly shows that RSC

is not used in Chinese surface dyslexic patients as a way of accessing a character's meaning. This is closely relevant to the characteristics of the phonological system of Chinese characters. Chinese characters are set up on the basis of a monosyllabic phonological system. As we have analysed in Chapter 2, the capacity of determining meaning by single character sound is far from sufficient (the ratio calculated for this capacity, ie. RDS, is 8.72%). The reason for this as our analysis has shown is that there is quite a high homophone ratio in Chinese characters, $H_r = 80.5\%$. Moreover, there is also a high average degree of homophone characters, $H_d = 7.851$. Therefore, it is quite difficult to access the meaning of the characters via the phonological route, and it is especially true for the way via PSC. Consequently, to a great extent, it must rely on the lexical route to get the character's meaning in reading Chinese characters. As a result, from the point of view of development, the route connecting a character's form to its meaning, i.e. Chinese lexical route, has been greatly developed. Thus, even in the case of surface dyslexia it is still difficult to completely block this route; on the contrary, this route can still work to some extent. Therefore there is no homophone confusion, but semantic errors coexist with it.

There are also some differences between Chinese deep dyslexic symptoms and alphabetic deep dyslexic symptoms. First, the Chinese semantic errors are found in all of the patients (with only one exception) and in many normals' speeded reading. This generality does not exist in reading disorders of alphabetic languages.

Secondly, in alphabetic languages users, deep dyslexia usually happens after large areas of the left hemisphere are damaged (Coltheart, et.al, 1987). Whereas in Chinese users, the deep dyslexic syndrome has not yet been found to be restricted to patients who have had large areas of the left brain damaged. Differences in these two respects imply that the underlying mechanism for the existence of the deep dyslexic syndrome in Chinese readers is not identical to that in alphabetic languages users.

As far as Chinese deep dyslexia is concerned, we need to look at the semantic errors made by the patients. There are two results obtained from analysis of these errors. One is that the types of semantic errors are similar to those found in the experiment with normal subjects. The other is that the semantic errors have some relationships with significs of combination-forms, but these relationships are, however, not the sole cause. The reason for this may lie in the fact that significs do not have precise meaning, and thus the readers can not rely on them to get the meaning of the character in most cases. However, in order to get a clearer picture of semantic errors in reading Chinese characters, further study of these two aspects on more deep dyslexic patients will be needed.

In addition to present evidence which demonstrates that reading Chinese characters is a multi-route process, the reading performances of Chinese patients also shown that there are some special features to be found in reading Chinese characters.

Chinese characters can be divided into single characters and

compound characters. When the whole meaning of a compound character can not be achieved, the meaning of the components of that character may still be accessed. This gives rise to the symptom which we have called associative dyslexia. A further symptom, which has been called compound dyslexia, depends on the exact relationship between the characters composing the word. The simpler and more apparent a logical relationship between the components of a compound word is, the better they are understood. The more complex and obscure the logical relationship is, the more likely is understanding to break down. The existence of compound dyslexia indicates that there is more to reading Chinese words than reading Chinese single characters.

Finally, speaking of the anatomical features of Chinese acquired dyslexic patients, they are generally (though not exactly) consistent with the neurological model of alphabetic acquired dyslexia in two main points: 1. The left hemisphere is dominant; 2. The areas in the occipital, parietal, and temporal lobes are involved. The neurology of these Chinese acquired dyslexic patients has further demonstrated that the conjunctive area of the parietal, temporal, and occipital lobes in the left hemisphere is important in reading Chinese characters. Ten out of eleven patients had damage in their left hemisphere, and the lesions mostly localized within the scope of the parietal, temporal, and occipital lobes. There was only one exception, a case where the right hemisphere was damaged. However, this case is special. He was a 12 year old boy. As we all know, the lateralization of the

function of the brain in children is not fully developed compared with that of adults. Moreover, from the point of the etiology of this patient (he suffered the Moya Moya disease, a congenital malformation of blood vessels), it may also be reasonable to make the deduction that the language function in the right hemisphere of this patient probably had developed as a compensation to the congenital malformation of blood vessels in the brain.

6. CONCLUSION

In summary, we can draw the following main conclusions from this research on acquired dyslexia in the reading of Chinese characters:

(1) Reading Chinese characters is not achieved by a single route, but is a multi-route process. Three routes were demonstrated in this clinical study: (a) the route from the whole character to sound; (b) the route from the phonetic to sound; and (c) the route from the character to meaning without mediation of sound. These three routes were shown to be independently used by patients. Moreover, it is important to emphasise here that surface dyslexic and deep dyslexic symptoms also exist in Chinese patients, in common with those of alphabetic acquired dyslexia.

(2) Due to the characteristics of Chinese script, Chinese acquired dyslexia has some special features. (a) There are some differences between Chinese deep as well as surface dyslexia and those of alphabetic dyslexia: the Chinese surface dyslexic syndrome

is not accompanied by homophone confusion, but coexists with the deep dyslexic symptoms. The Chinese deep dyslexic syndrome manifests as a common phenomenon in Chinese reading disorders. (b) associative and compound dyslexic symptoms exist in Chinese patients, connected with special types of Chinese characters.

CHAPTER 5

DEVELOPMENTAL READING DISORDERS FOR CHINESE CHARACTERS

5.1. INTRODUCTION

Developmental dyslexia is the inability of some children to learn to read despite normal intelligence, normal vision, normal hearing, and adequate education. It is not uncommon in the learner of alphabetic languages. Generally speaking, 5 to 10 per cent of school children are estimated to have this developmental disability (Tarnopol, et al. 1981). More boys suffer this disability than girls. Some central features of developmental dyslexia have been commonly described: marked difficulties in spelling, frequent letter reversals in both reading and writing, comprehension problem, attention problem, and mild expressive and receptive difficulties in spoken language.

Studies of developmental dyslexia have found that dyslexic children may have difficulty in mastering the phonic aspect of reading, they may delay at a particular developmental stage, and incomplete cerebral lateralisation might also underlie the disorder. Among the possible causes of developmental dyslexia, phonological awareness has been emphasised. Moreover, different subtypes of developmental dyslexia have been reported, i.e. developmental deep dyslexia, developmental surface dyslexia, and developmental phonological dyslexia.

The purpose of studying developmental reading disorders for Chinese characters is to find out whether there is a script effect

in reading development due to the characteristics of Chinese characters especially in relation to their phonological and configurational nature. This research will provide information from large scale observations in the progress of children's reading development. It will consequently facilitate clinical case study on acquired dyslexia and laboratory experimental study on normal adult's reading process.

5.2. DESIGN

In order to find out whether there is a script effect in reading peculiar to the characteristics Chinese characters by surveying developmental reading disorders in Chinese, a questionnaire was made up.

The questionnaire was to be filled in by language teachers who, according to the education system, are in charge of studies in their classes. In filling in the questionnaire, teachers first of all had to give the number of male and female students as well as the names of left-handed students in their classes. Then, 13 questions were asked. These questions were:

Whether there are students in class, who had:

(1) Difficulty with Pin-Yin: often unable to correctly read and write out Pin-Yin for new characters.

(2) Pin-Yin letter confusion: often confuse "b" with "d" and "p" with "q".

(3) Difficulty with dictation: often unable to perform dictation task well.

(4) Difficulty with listening comprehension: often unable to correctly and quickly understand and carry out instructions made by the teacher.

(5) Confusion with positions of radicals: sometimes putting the radicals in the wrong position when writing Chinese characters.

(6) Mirror writing: sometimes mirror writing Chinese characters.

(7) Confusion with visually similar characters:

(a) When writing characters, often substituting visually similar ones and feeling confused by them.

(b) When reading books, often misunderstanding visually similar characters and feeling confused by them.

(8) Confusion with homophones: when writing characters, often substituting homophones again with feelings of confusion.

(9) Difficulty with visual memory: obviously slow in copying Chinese sentences, unable to remember a short sentence (seven or less than seven characters) at a glance: and taking much more time than other students to remember the configurations of new characters when learning new words.

(10) Difficulty with attention: having difficulty with concentration, often unable to focus attention in order to finish a task.

(11) Difficulty with orientation: often confusing left/right with right/left, and getting perplexed with other orientations.

(12) Hyperactive and restless: unable to sit still, unable to keep hands and legs still when standing, and often over responsive.

(13) Tardy in sensory responses and movements: slow in reactions, indifferent to new things, and less active.

After these, a judgement was asked to be made on developmental reading disorder pupils with the criteria being given as to whether there are students in the class who have:

Reading difficulty: having normal intelligence, and getting good marks in courses they have learnt, but having obvious difficulty when reading is required. The speed of reading is slow compared with that of other students, and there is also less comprehension. When reading sentences, a laboured manner of reading is noticed that is characterised by reading characters slowly one by one; they are unable to grasp the meaning when they finish reading a paragraph, and often need to review it a few times in order to understand its main idea.

Finally, extra questions were asked which were optional. They were:

(a) According to your experience, do you think students with reading difficulty exist in your class?

(b) Are there any other problems concerned with reading Chinese characters?

(c) Have you ever noticed some special recognition problems in reading Chinese characters?

These questions are designed to serve two purposes. One is to make this study as compatible as possible with that in alphabetic languages to meet some common requirements for diagnosing developmental reading disability. In this respect, we

hope to see whether or not Chinese developmental reading disordered pupils share any common features with developmental dyslexic pupils who use an alphabetic language. The other is to find out whether there are any peculiar problems in reading Chinese characters. Through this we hope to see the effect of the script, and some special features connected with reading Chinese characters.

For the purpose of making this study as compatible as possible with that in alphabetic languages, and meeting the requirements of diagnosing developmental reading disability in the light of some common features, questions 1, 2, 10, 11, 12, and 13 were proposed. Question 1 and 2 are concerned with the problems of reading Pin-Yin. Pin-Yin, as a Chinese alphabet, can be thought as the counterpart of an alphabetic script in the Chinese language. Although Chinese characters differ from alphabetic words to a great extent, Pin-Yin does not. This gives us a chance to compare reading them and reading Chinese characters, and such comparison is an important aspect in the survey. Questions 10, 11, 12 and 13 are concerned with some common symptoms which usually come with developmental dyslexia.

For the purpose of finding out whether there are any special features in reading Chinese characters, questions 3, 4, 5, 6, 7, 8 and 9 were proposed. These questions are connected with two aspects of Chinese characters, one is the configuration structure, the other is the phonological structure. The questions concerning the Chinese script's configuration aspect are 5, 6, 7 and 9. The questions concerning Chinese character phonological structure are

3, 4 and 8.

The judgement required on developmental reading disordered pupils was based on the criteria which satisfies the common diagnosis norm for developmental dyslexia in alphabetic languages.

5.3. METHOD

The questionnaires were given to headmasters of the elementary schools being surveyed. They were then distributed among language teachers from grade 2 to grade 6 to fill in. The reason why grade 1 was not included was that the pupils in grade 1 have not got enough time to manipulate Chinese characters, therefore it is not suitable to do a survey in reading Chinese characters on them. Money (to the value of 3 yuan RMB, equal to 50 p) was payed to each teacher to fill in a questionnaire. The questionnaires were collected personally rather than by mailing in order to make sure that they had been properly completed. Since the questionnaire was asked to be fully completed with name, sex and handedness of reading disordered pupils, it was therefore not a simple task and would not be expected to be completed the first time around. If the questionnaire was not completed in accordance with requirements, it was then given back to be filled in again.

5.4. RESULTS

The population of this survey is 8106 in Haidian District of Beijing, the People's Republic of China. This population did not include rural areas, moreover it is localized in Haidian district

which is a comparatively highly educated area in Beijing. The reason for this is that since much more attention has been paid to this area's education, if there is any reading problem, then the teacher will very likely know and the problem therefore will be examined or observed more carefully than that in other areas where education has not had the same concern so that teachers will possibly not even know what reading disability means.

Eight elementary schools were involved in this survey, they are: Shuang Yu Shu number 1 school; Shuang Yu Shu number 2 school; Da Zhong Si school; The attached primary school of People's university; The attached primary school of Beijing university; Zhong Guan Cun number 1 school; Zhong Guan Cun number 2 school; and Zhong Guan Cun number 3 school.

There were 4184 male pupils and 3922 female pupils being surveyed. They were in grade 2 to grade 6. Their age range covered from 7 to 11 (with some exceptions).

Handedness was surveyed in this population, and 217 pupils were reported to be left-handed. It should be noticed that the judgement on handedness could not refer to writing, because in China pupils are forced to use their right hand to write when they come to school, and no left-hand-writing is allowed according to the regulations. Therefore handedness was judged on the following selections: (a) which hand is used for eating with chopsticks. (b) which hand is used for throwing things. (c) which hand is used for playing Ping-Pong (China's favourite sport).

5.4.1. Ratio of developmental reading disorder pupils

Through this survey, among 8106 pupils, 156 students were regarded as having reading disability in the light of the criteria of developmental dyslexia by their teachers. They had normal intelligence and good marks in courses they had engaged in, but their reading was obviously slower than others and reading comprehension was obviously tardy; In reading, a rigid character-by-character phenomenon often appeared and they often failed to grasp the main idea soon after finishing reading a paragraph, consequently repeat reading often happened.

The ratio of reading disorder pupils in this survey was 1.92%. Obviously, this ratio was much lower than what has usually been found in the users of alphabetic languages.

5.4.2. The ratio of reading difficulty with Pinyin

Difficulty in reading Pinyin was surveyed in this research by Questions 1 and 2 in the questionnaire. There were 497 pupils who were regarded to be unable to correctly read and write out Pinyin for new characters. Thus the occurrence of this problem was 6.1%. There were 428 pupils who were regarded to have Pinyin letter confusion. Thus the occurrence of this problem was 5.3%.

In more detail, 42 reading disordered pupils and 455 normal pupils were regarded to be unable to correctly read and write Pinyin for new characters, and thus, the ratio of this problem in reading disorder pupils and in normal pupils was 26.92% and 5.72%. 41 reading disordered pupils and 387 normal pupils were regarded as having Pinyin letter confusion, and thus, this problem in reading disordered pupils and normal pupils was 26.28% and 4.86%.

Obviously, unlike the ratio of reading disordered pupils, these ratios of reading difficulty with Pinyin were comparable with readers of other alphabetic scripts.

5.4.3. Occurrence of symptoms

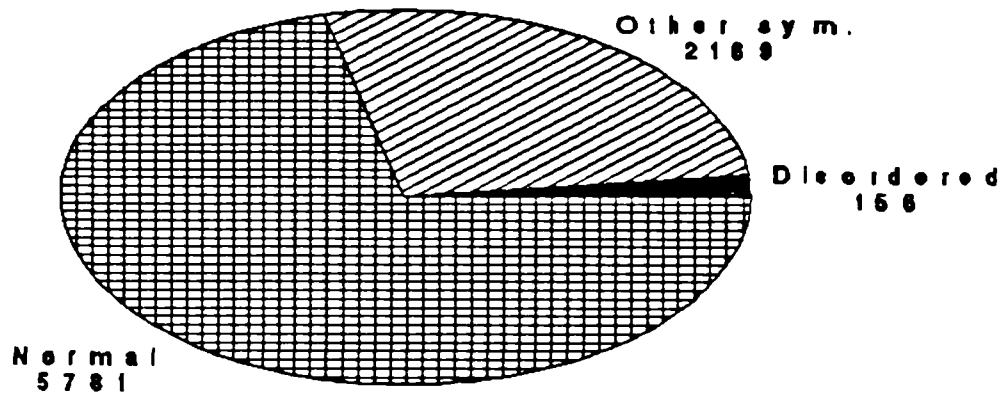
Through this survey, many symptoms as listed in the questionnaire were revealed. They were shared by reported reading disordered pupils and other students who were not regarded as having serious reading disability by their teachers. The number of students who had any of these symptoms but not regarded as having reading disability was 2169, therefore the occurrence of these symptoms in the total number of pupils being surveyed was 26.76 %. Quite apparently, this ratio was much higher than the ratio of reading disorder pupils.

The general occurrence of symptoms and the ratio of reading disorder pupils is represented in Table 5.1 and Figure 5.1.

Table 5.1 General Occurrence of Symptoms

	population	disordered	other symptoms
number	8106	156	2169
%		1.92	26.76

Figure 5.1 General Occurrence of symptoms



5.4.4. Distribution of symptoms

The questionnaire used in this survey listed 14 symptoms concerning reading behaviour. Of these 14 symptoms the last one was used for judging developmental reading disorder pupils on the basis of the common criteria of diagnosing developmental dyslexia which gave the number of reading disorder pupils. All the other 13 symptoms were involved in the reading survey from various aspects either directly related to the reading processes or indirectly in terms of common features which usually come with reading disability. These 13 symptoms had different occurrences, in other words, the number of pupils for each symptom was different, and their percentages in total surveyed pupils are represented in Table 5.2 and Figure 5.2.

Table 5.2 The distribution of symptoms in pupils being surveyed

	Q1	Q2	Q3	Q4	Q5	Q6	Q7a	Q7b	Q8	Q9	Q10	Q11	Q12	Q13
Num.	497	428	567	431	362	142	574	334	550	584	697	304	582	327
%	6.1	5.3	7.0	5.3	4.5	1.8	7.1	4.1	6.8	7.2	8.6	3.8	7.2	4.0

Figure 5.2 Distribution of symptoms (1)

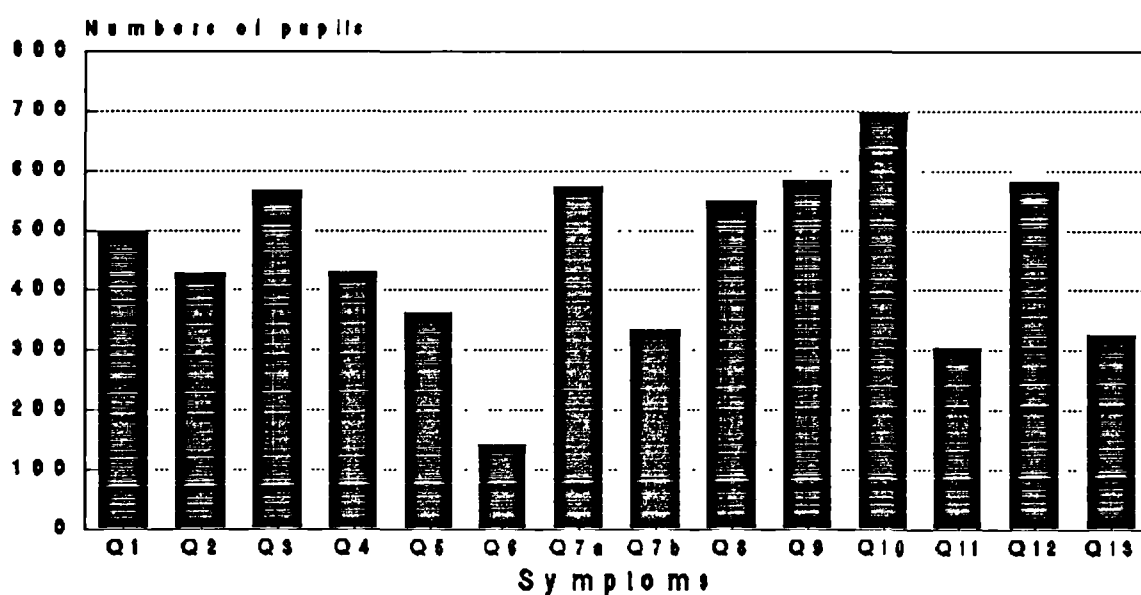


Table 5.2 and figure 5.2 illustrate a general distribution of symptoms of all the pupils who had any of these 13 symptoms. The pupils regarded as reading disordered by their teachers are included there and the distribution has taken their condition into consideration.

To make the distribution much clearer, it is necessary to separate the distribution into two parts: one is the distribution

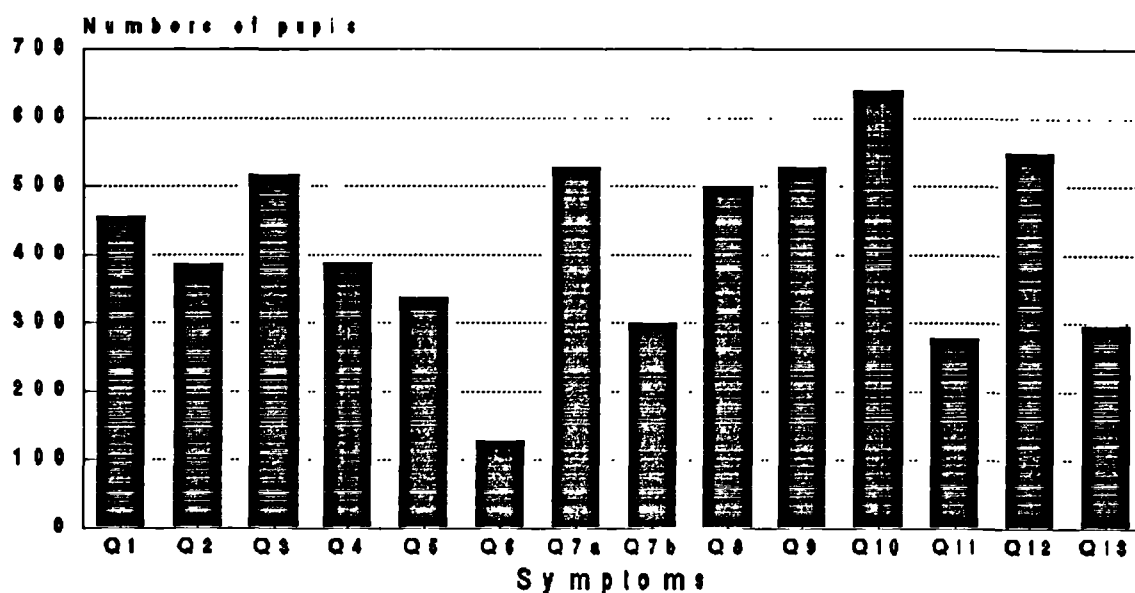
in the population without reported reading disorder pupils; another is the distribution in the reported reading disorder pupils.

By taking out reported reading disorder pupils, we can get Table 5.3 and Figure 5.3, which present and illustrate the distribution of symptoms without reported reading disorder pupils. In Table 5.3, two types of percentage of pupils having each of these 13 symptoms are presented, one is based on the total number of pupils being surveyed, another is based on the total number of pupils who had any of these symptoms. In Figure 5.3, distribution is figured out on the basis of symptoms.

Table 5.3. The distribution of symptoms in pupils without reported reading disorder

	Q1	Q2	Q3	Q4	Q5	Q6	Q7a	Q7b	Q8	Q9	Q10	Q11	Q12	Q13
Num	455	387	517	389	337	129	529	300	500	529	640	277	549	297
% (1)	5.6	4.8	6.4	4.8	4.2	1.6	6.5	3.7	6.2	6.5	7.9	3.4	6.8	3.7
% (2)	21	18	24	18	16	6	24	14	23	24	30	13	25	14

Figure 5.3 Distribution of symptoms (2)

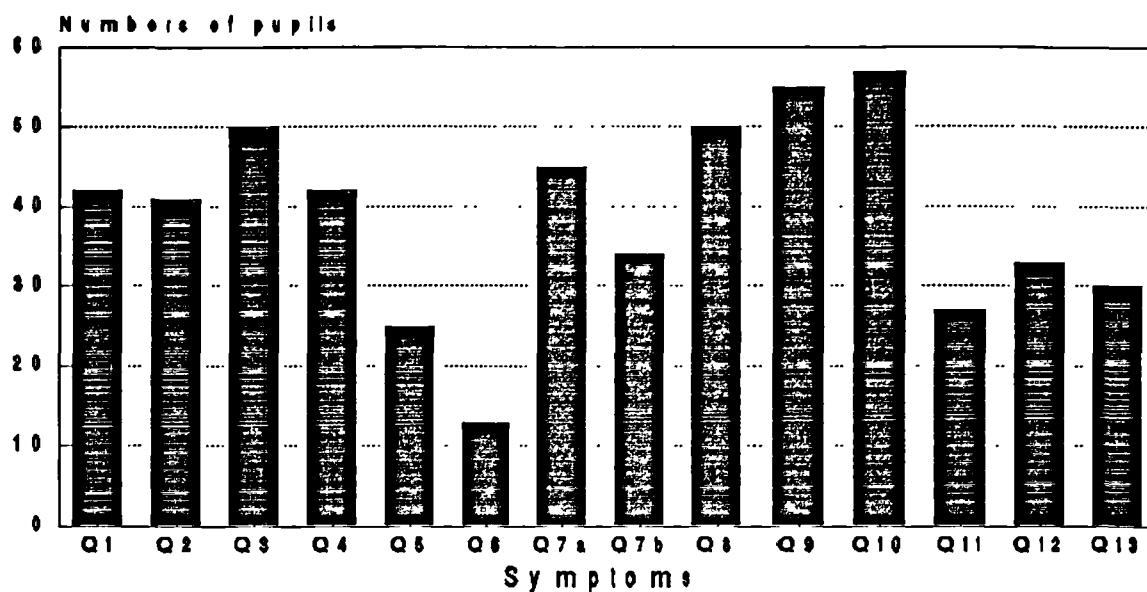


By calculating the number of pupils who had any of the symptoms in reported reading disorder students, I can then figure out the distribution of symptoms in reported reading disorder pupils in which the percentage of each symptom is calculated on the basis of the total number of reported reading disorder pupils. This distribution is presented in Table 5.4 and Figure 5,4.

Table 5.4. The distribution of symptoms in reported reading disordered pupils

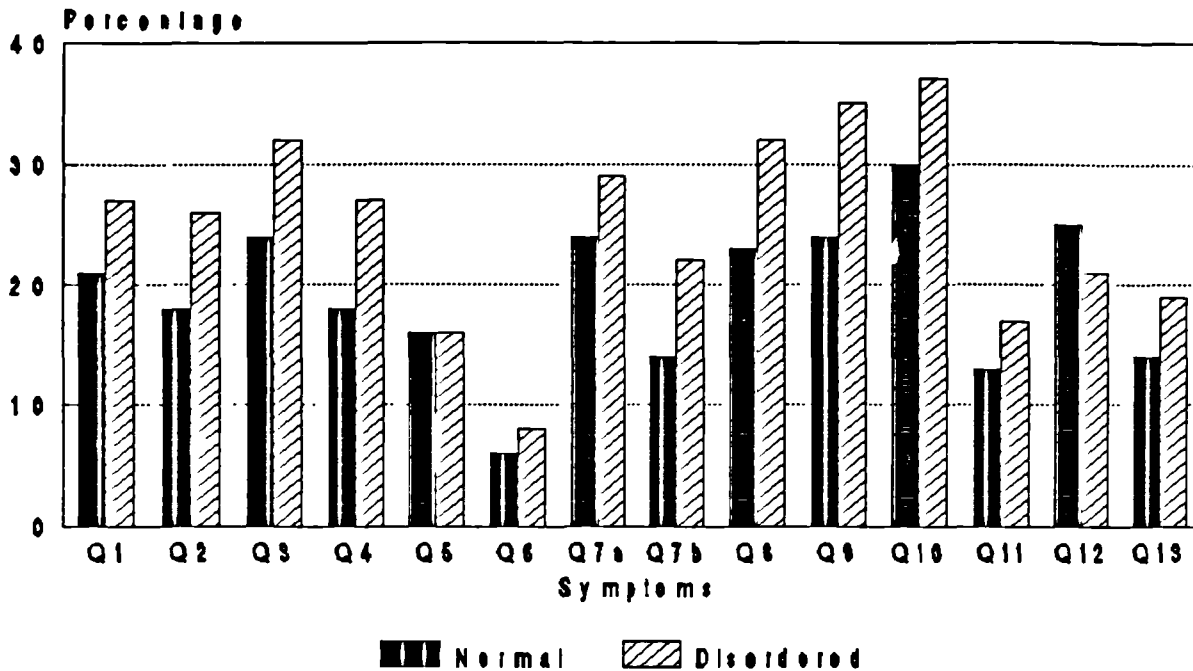
	Q1	Q2	Q3	Q4	Q5	Q6	Q7a	Q7b	Q8	Q9	Q10	Q11	Q12	Q13
Num.	42	41	50	42	25	13	45	34	50	55	57	27	33	30
%	27	26	32	27	16	8	29	22	32	35	37	17	21	19

Figure 5.4 Distribution of symptoms (3)



Putting together the distribution of symptoms without reported reading disordered pupils with the distribution of symptoms in reported reading disordered pupils, we get Figure 5.5 which allows us to compare these two distributions.

Figure 5.5 Distribution of symptoms (4)



As we can see from the figures, the percentage of each symptom (including problems with Pin-Yin) in the distribution is generally higher in reported reading disorder pupils than that of non-reported reading disorder pupils (only one exception, Q12).

It is also quite clear that the general features or outlines of either distribution in non-reported reading disorder pupils or distribution in reported reading disorder pupils is quite similar. This general feature needs to be further analyzed.

5.4.5. Correlation and factor analysis

To further analyze the relationship between the ratio of reported reading disorder pupils and the occurrence of each symptom, a correlation analysis is carried out. Table 5.5 presents

the correlations between reading disorder and all the other symptoms respectively.

Table 5.5 Correlations between reading disorder and other symptoms

	Q1	Q2	Q3	Q4	Q5	Q6	Q7a
r	0.042	0.060	0.058	0.063	0.009	0.033	0.032
	Q7b	Q8	Q9	Q10	Q11	Q12	Q13
r	0.061	0.059	0.069	0.049	0.038	-0.017	0.045

As we can see from the table, reading disorder is revealed to have no strong correlation with any particular symptoms.

To further analyze symptoms revealed in the survey, a factor analysis is carried out on the results from either reported reading disorder pupils or all the symptoms holders.

In the correlation matrix of surveying results of reported reading disorder pupils, sex, handedness and grade are revealed to have no strong correlations with particular symptoms (see table 1 in appendix B). A similar result can be seen from the correlation matrix of surveying results of all the symptom holders (see table 2 in appendix B).

From correlations among symptoms, we can see that all the symptoms have some relationship to each other in different degrees. Through factor analysis, two factors are detected from the symptoms in reported reading disorder pupils. Table 5.6 presents the results of this factor analysis.

Table 5.6 Factor analysis on reported reading disordered pupils

	Factor A	Factor B
Q3	0.827	0.000
Q13	0.734	0.000
Q4	0.682	0.309
Q1	0.667	0.522
Q9	0.665	0.297
Q8	0.661	0.309
Q7a	0.573	0.429
Q10	0.508	0.440
Q6	0.000	0.722
Q11	0.000	0.679
Q7b	0.329	0.649
Q5	0.331	0.604
Q2	0.421	0.549
Q12	0.345	0.365

(Sorted rotated factor loadings (pattern))

According to the results, Difficulty with dictation and Tardy in sensory responses and movements primarily belong to factor A, Mirror writing and Difficulty with orientation primarily belong to factor B, all the other symptoms partially belong to both factor A and factor B. Factor A seems to reflect problems in sensory and motor aspects and factor B seems to reflect problems in spatial position.

Through factor analysis on symptoms in all holders, four

factors are detected. Table 5.7 present the result of this factor analysis.

Table 5.7 Factor analysis on symptom holders

	Factor A	Factor B	Factor C	Factor D
Q7a	0.671	0.000	0.000	0.000
Q8	0.617	0.000	0.000	0.000
Q5	0.591	0.000	0.000	0.000
Q7b	0.549	0.000	0.000	0.000
Q1	0.508	0.430	0.000	0.000
Q13	0.000	0.672	0.000	0.000
Q4	0.000	0.519	0.000	0.000
Q12	0.000	0.000	0.789	0.000
Q10	0.000	0.000	0.710	0.000
Q11	0.000	0.000	0.000	0.750
Q6	0.423	0.000	0.000	0.609
Q9	0.324	0.485	0.000	0.000
Q3	0.424	0.419	0.000	0.000
Q2	0.451	0.297	0.000	0.000
Q14	0.000	0.339	0.000	0.271

(Sorted rotated factor loadings (pattern))

According to the result, Confusion with visually similar characters in writing, Confusion with visually similar characters in reading, Confusion with positions of radicals and Confusion with homophones primarily belong to factor A; Difficulty with listening comprehension and Tardiness in sensory responses primarily belong to factor B; Hyperactivity and restlessness and Difficulty with

attention primarily belong to factor C; Difficulty with orientation primarily belongs to factor D; Difficulty with Pin-Yin, Difficulty with visual memory, Pin-Yin letter confusion, and Difficulty with dictation partially belong to both factor A and factor B; Confusion with position of radicals partially belongs to both factor A and factor D; Reading disability in the light of a common criterion partially belongs to both factor B and factor D. According to this factor analysis, it seems that factor A probably reflects a spatial position problem; factor B probably reflects a sensori-motor problem; factor C probably reflects a MBD (Mild Brain Disfunction, a common syndrome in children); factor D probably reflects a problem in orientation.

5.4.6. Handedness

(1) Left-handed ratio

As mentioned before, among 8106 pupils being surveyed, 217 students were reported to be left-handed according to the classification for left-handedness in this survey, the ratio of left-handed pupils therefore was 2.68 %. Compared with the ratio of left-handed people in general which is about 10 % (Kolb, et al. 1985; Gilinsky, 1984), the ratio of left-handed pupil in this survey is lower and this is possibly due to multiple social and cultural reasons.

(2) Handedness and reported reading disability

Among 217 left-handed pupils, 12 were reported to have reading disability, half were male and half were female. The ratio of reading disordered pupil in this left-handed population was 12

/ 217 = 5.53 %. This ratio is higher than that in the population without left-handed pupils which can be calculated by excluding left-handed pupils from the total population, and the result was $144 / 7889 = 1.83 \%$. The difference between them is significant, $\chi^2 = 14.285$, $P < 0.005$.

(3) Handedness and symptoms

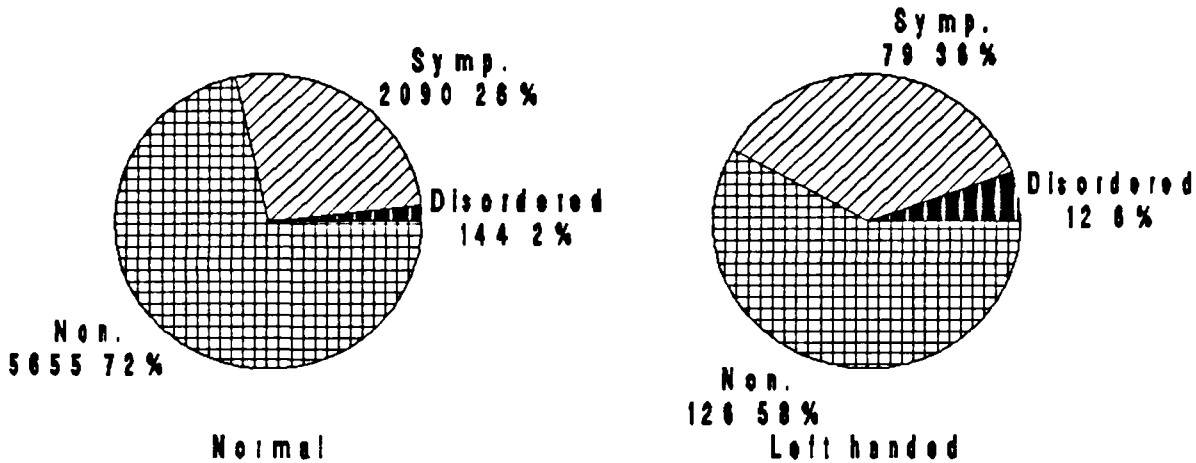
Apart from reported reading disordered pupils, in this left-handed population, there were 79 students who had symptoms in this survey, therefore the occurrence of symptoms in this left-handed population was $79 / 217 = 36.41 \%$. Obviously, this occurrence of symptoms is higher than that in the population without left-handed pupils which can be calculated by excluding left-handed pupils from the total population, and the result was $2090 / 7889 = 26.49 \%$. The difference between them is significant, $\chi^2 = 5.698$, $P < 0.025$.

Table 5.8 and Figure 5.6 present the number of reported reading disorder pupils and the occurrence of symptoms in left-handed students in comparison with that in non left-handed pupils.

Table 5.8 The number of reported reading disorder pupils and the occurrence of symptoms in left-handed pupils comparing with that in non left-handed pupils.

	Non-left-handed pupils	left-handed pupils
Number of pupils being surveyed	7889	217
Number of reading disorder pupils	144 (1.83%)	12 (5.53%)
Number of those having other symptoms	2090 (26.49%)	79 (36.41%)

Figure 5.6 Handedness difference



5.4.7. Sex

(1) Sex and reported reading disability

There were more girls than boys being reported to have reading disability. Among 4184 boys, 110 pupils were thought of as having reading disability; while among 3922 girls, the number of pupils being thought of as having reading disability was 46. The ratio of reading disorder pupils for boys was $110 / 4184 = 2.63\%$; while the ratio of reading disorder pupils for girls was $46 / 3922 = 1.17\%$. The difference between sexes is very significant, $\chi^2 = 21.896$, $P < 0.001$.

(2) Sex and symptoms

In addition to sex difference in the ratio of reported reading disorder pupils, there was also obvious difference in the

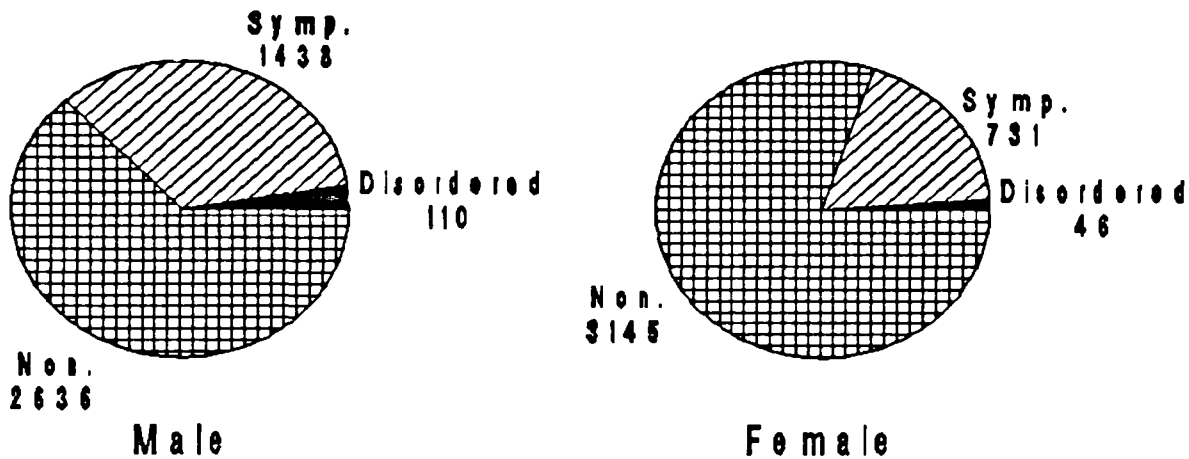
occurrence of symptoms between boys and girls. Excluding reported reading disorder pupils, 1438 boys were found to have symptoms, while for girls, the number was 731. The occurrence of symptoms for boys was $1438 / 4184 = 34.37\%$; while the occurrence for girls was $731 / 3922 = 18.64\%$. The difference between sexes is very significant, $\chi^2 = 148.861$, $P < 0.001$.

Table 5.9 and Figure 5.7 present the number of male / female reported reading disorder pupils and the occurrence of symptoms in both sexes.

Table 5.9 The number of reported reading disorder pupils and the occurrence of symptoms in boys and girls

	Boys	Girls
Number of pupils being surveyed	4184	3922
Number of reading disorder pupils	110 (2.63%)	46 (1.17%)
Number of those having other symptoms	1438 (34.37%)	731 (18.64%)

Figure 5.7 Sex difference



5.4.8. Grade

(1) Grade and reported reading disorder pupils

Of 8106 pupils being surveyed in elementary school, 1720 were in grade 2, 1853 were in grade 3, 1674 were in grade 4, 1493 were in grade 5, and 1366 were in grade 6. Among 1720 grade 2 students, 44 were regarded as having reading disability, the ratio of reported reading disorder pupils in this grade was 2.56%. Among 1853 grade 3 students, 34 were regarded as having reading disability, the ratio in this grade was 1.83%. Among 1674 grade 4 students, 29 were regarded as having reading disability, the ratio in this grade was 1.73%. Among 1493 grade 5 students, 28 were regarded as having reading disability, the ratio in this grade was 1.88%. Among 1366 grade 6 students, 21 were regarded as having

reading disability, the ratio in this grade was 1.54%. There is a strong negative correlation between grade and the ratio, $r = -0.813$.

(2) Grade and symptoms

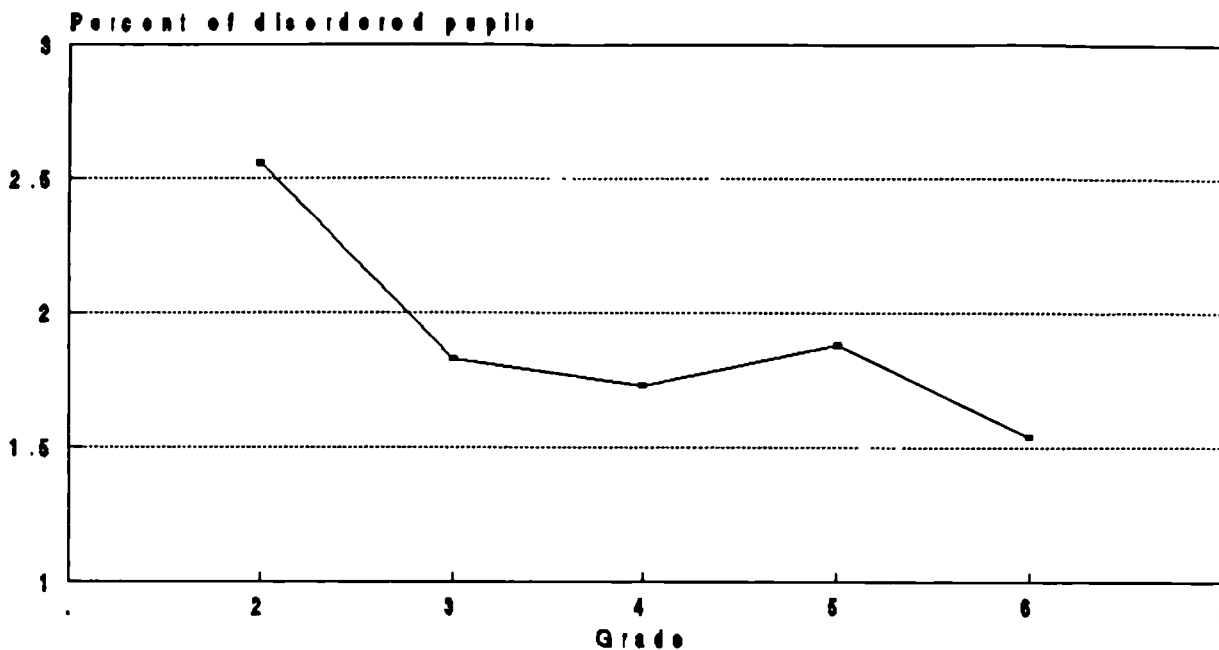
Excluding reported reading disorder pupils, in grade 2, 482 students were found to have symptoms, the occurrence of symptoms was 28.02%; in grade 3, 483 students were found to have symptoms, the occurrence in this grade was 26.07%; in grade 4, 437 students were found to have symptoms, the occurrence in this grade was 26.11%; in grade 5, 432 students were found to have symptoms, the occurrence in this grade was 28.94%; in grade 6, 335 students were found to have symptoms, the occurrence in this grade was 24.52%. The correlation between grade and the occurrence is -0.373 .

Table 5.10 and Figure 5.8 present ratio of reported reading disordered pupils and the occurrence of symptoms in each of 2 to 6 grades.

Table 5.10 The ratio of reading disability and occurrence of symptoms in 2 to 6 grades

Grade	Number of pupils being surveyed	Number of reading disordered pupils	Number of those having other symptoms
2	1720	44 (2.56%)	482 (28.02%)
3	1853	34 (1.83%)	483 (26.07%)
4	1674	29 (1.73%)	437 (26.11%)
5	1493	28 (1.88%)	432 (28.94%)
6	1366	21 (1.54%)	335 (24.52%)
Sum	8106	156	2169

Figure 5.8 Grade difference



The table and figure show that in every grade, the occurrence of symptoms was higher than the ratio of reading disability.

Moreover, a general trend is revealed which is that as the grade ascends, the ratio of reading disability and the occurrence of symptoms descend, though it is not steady.

5.4.9. Handedness, sex and grade interrelation in reading symptoms

Putting handedness, sex and grade together, some general features of their interrelations in reading symptoms can be had.

Table 5.11 gives the number of left-handed students and the number of reported reading disorder students in both sexes and in each of the 2 to 6 grades.

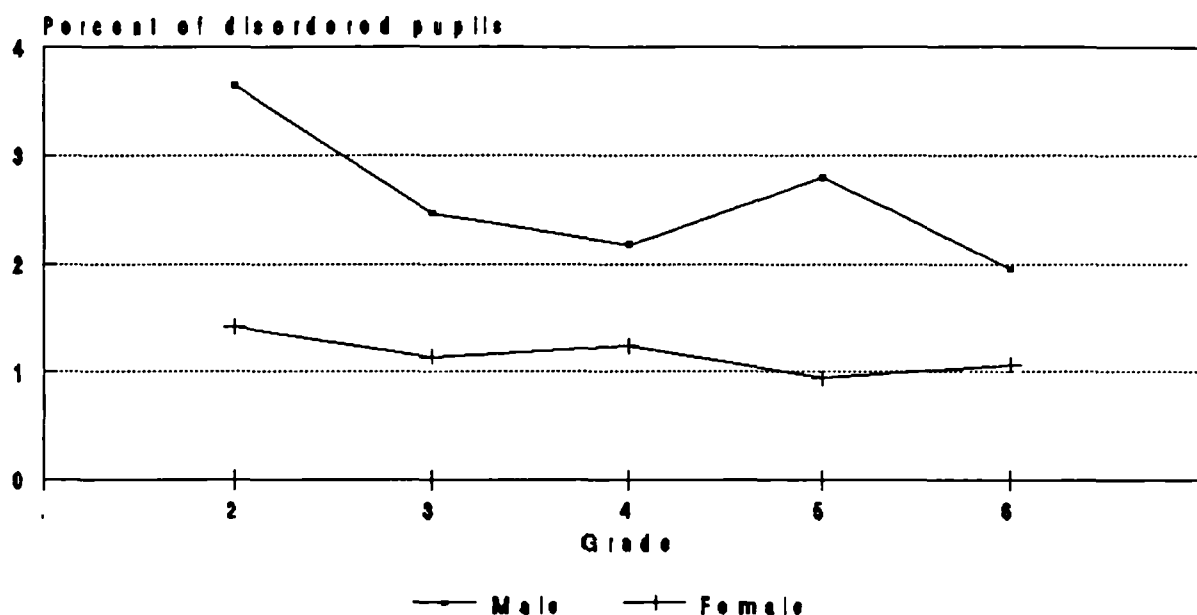
Table 5.11 the number of left-handed pupils and number of reported reading disorder pupils in both sexes and in each of the 2 to 6 grades

G	Male	Female	Left-handed			Disordered					
			M	F		Male			Female		
						Left	Normal	Sum	Left	Normal	Sum
2	877	843	44 5.02%	38 4.51%	1	31 3.65%	32	1	11 1.42%	12	
3	970	880	32 3.29%	18 2.05%	1	23 2.47%	24	1	9 1.14%	10	
4	870	804	25 2.87%	11 1.37%	2	17 2.18%	19	1	9 1.24%	10	
5	750	743	18 2.4%	8 1.08%	0	21 2.8%	21	2	5 0.94%	7	
6	714	652	17 2.38%	6 0.92%	2	12 1.96%	14	1	6 1.07%	7	
S	4148	3922	136 3.25%	81 2.07%	6	104 2.63%	110	6	40 1.17%	46	
T	8106		217 2.68%			156 1.92%					

As can be seen from the table, the ratio of reported reading disordered pupils in male students are generally higher than that in female students. This difference is significant, $t = 4.73$, $P < 0.01$. As the grade ascends these ratios in both sexes descend. There is a strong negative correlation between male disordered and grade, $r = -0.730$. There is also a strong negative correlation between female disordered and grade, $r = -0.787$. However, the number of left-handed reported reading disorder pupils show no significant difference between male and female and also not much change when the grade ascends.

Figure 5.9 illustrates the percentage of reported reading disorder pupils in male and female students in each of the 2 to 6 grades.

Figure 5.9 Sex, grade and retard.



5.5. DISCUSSION

From the results of the survey a general picture of the developmental aspect of reading Chinese characters is revealed which has the following features:

(1) Low ratio of reading disability for Chinese characters

One remarkable result of this survey is that there is a quite low ratio of reading disability in the light of the common criteria of developmental dyslexia. The reason for this may be quite

complicated. The low ratio of reading disability may be a realistic indicator of the characteristics of reading Chinese characters, or may be caused by some other factors. There is no standard reading test existing in China, therefore it is unrealistic to have a more objective assessment on the ratio of actual reading disability at this time. Moreover, since the problem of reading disability has never come to be a public concern, we cannot exclude the possibility that the teachers who filled in the questionnaire were not aware of the reading disorder pupils. However, such a low ratio of reading disability does reflect something realistic, and if we compare this with what happens in alphabetic languages it does imply that the script has an effect on reading because the ratio of developmental dyslexia in alphabetic languages on the whole is much higher.

(2) The discrepancy of problems with Pin-Yin and characters

An important aspect in this survey is to compare reading Pin-Yin and reading characters. What we found in this aspect is the fact that although the ratio of reading disability for Chinese characters is low, the ratio of the problems in reading Pin-Yin nevertheless not so low. This discrepancy between reading Pin-Yin and reading characters further indicates the relationship between reading disability and scripts.

Moreover, the details of the problem with Pin-Yin share the same features as that with alphabetic words.

As we know, one significant symptom of developmental dyslexia of alphabetic languages is the confusion between some similar

letters, especially b and d, p and q which have confusable, revolved orientational properties. Developmental dyslexic children are found to have obvious difficulties in discriminating and recognizing these similar letters. They more easily mistake b for d, and q for p (Orton, 1925, 1937; Hermann, 1959). In this survey, such phenomenon was also revealed in reading Pin-Yin in which the same letters, b, d, p, q were used. This symptom nevertheless was not unique to reported reading disordered pupils, as we have seen from the survey this confusion with similar letters was also found in other pupils.

However, the occurrence of the letter confusion symptom was higher in reported reading disorder pupils than in the other population.

The existence of this phenomenon in Chinese pupils' reading Pin-Yin reveals a similarity in reading behaviour provided reading materials are alphabetic ones.

This finding of confusion with b and d, p and q in Chinese students' reading Pin-Yin is consistent with some other studies and observations.

In a recognition experiment, Pin-Yin letters, a, b, d, p and q were presented to Chinese pupils for recognizing, the result showed significantly more confusion happened between b and d, p and q (Cao, 1965).

According to a survey of learning achievement of the Chinese language carried out in the Shanghai area, one quarter of grade six pupils examined had a problem with recognizing b, d, p and q. They

were found to be confused with b and d, p and q. For example, some of them wrongly spelled "pan" as "qan", "den" as "ben", "pi" as "qi", and "qiu" as "piu" (Zeng, 1986).

The similarity between Chinese reading disorder pupils and developmental dyslexic pupils of alphabetic languages in the matter of confusion with letters b and d, p and q is to be expected: the human brain is the same everywhere, if the reading materials are similar, then the function of the brain in dealing with them would not differ very greatly. Although Chinese characters are very different from alphabetic letters, Pin-Yin, as the alphabetic counterpart in the Chinese language is nevertheless not very different from them, and the confusion with similar letters, as a common symptom of reading difficulty in alphabetic script therefore will very likely be seen in reading Pin-Yin.

This is also consistent with other studies. In the survey of learning achievement of Chinese language carried out in the Shanghai area mentioned above, those pupils who had problem with Pin-Yin in confusion of "b" with "d", and "p" with "q", had, however, no obvious difficulty in learning Chinese characters. As the survey showed, they already knew well 3000 Chinese characters. Although they mistook "p" for "q" and "b" for "d" in their spelling, they could anyway correctly write and understand the characters corresponding to the Pin-Yin they had misspelled. For example, they had wrongly spelled Pin-Yin for 攀 (means climb, pronounced as pān for 攀, dēn for 登) as "gān bēn", but they could correctly write 攀 登 out and understand precisely.

Moreover, according to the same survey, there were some children who could not learn Pin-Yin well at all, even with great help from their teachers, such children still make no significant progress in this learning process. But these children could learn Chinese characters alone quite well without many difficulties (Zeng, 1986).

This difference between learning Chinese characters and alphabetic script was more obvious in the research on American developmental dyslexic children in which those children were found to have no obvious difficulty in learning Chinese characters and their reading problems seemed to be overcome by using Chinese characters to facilitate their learning process (Rozin, et al. 1971).

(2) No significant correlation between reported reading disability and other symptoms

The results of this survey show reading disability has no particular correlation with other symptoms (see table 3.5). This seems quite peculiar and quite different from what we have seen in studies on developmental dyslexia of alphabetic languages in which reading disability has been revealed to have strong correlations with many of the symptoms which are included in this survey.

This reflects the fact that reading disability in terms of the common criteria is certainly an unfamiliar concept to Chinese teachers.

(3) High occurrence of other symptoms

As we have seen from the results of the survey, the occurrence of different symptoms is much higher than the ratio of

reading disorder pupils. The occurrence of different symptoms is 26.76%, while the ratio of reading disorder pupils is only 1.96%. This implies that even though according to the common criteria very few pupils fit the category of having reading disability, the actual problems of reading Chinese characters nevertheless cannot be neglected.

(4) Similarity between distribution of symptoms in reported reading disorder pupils and pupils without them

The outline of distribution of symptoms whether in the population of reported reading disorder pupils or in the population of pupils without them is quite similar. This implies there is a common feature of reading symptoms for Chinese characters. Moreover, this similarity also demonstrates that reading disability for Chinese characters in the light of common criteria of developmental dyslexia could be regarded as something belonging to the common feature of reading symptoms for Chinese characters. This is consistent with the fact that the reported reading disability in the light of the common criteria of developmental dyslexia has no correlation with individual symptoms.

The above features of the developmental aspect of reading Chinese characters have an implication: there seems to be a reasonable distinction between reported reading disability and the problems of reading Chinese characters.

The reading disability was required to be judged on the basis of the common criteria for diagnosing developmental dyslexia. These criteria however have been set up on the basis of studies of

alphabetic language users. The key problem therefore probably arises here: it is possible that the criteria for classifying developmental dyslexia is not suitable for determining Chinese reading disordered pupils, or perhaps it is actually another story for Chinese reading disability. However, one thing is clear: there are some pupils who were regarded as being reading disordered students in the light of the common criteria used for developmental dyslexia, and there are also more pupils who were not categorised as reading disordered students but had problems in relation to reading Chinese characters. Considering this reality, it is reasonable to acknowledge the fact that reading disability for Chinese characters on the basis of the common criteria for developmental dyslexia and the reading problems with Chinese characters are two separate issues. There are more problems in reading Chinese characters than developmental dyslexia alone (Note that dyslexia is not a term familiar to Chinese teachers). As mentioned before, there is no standard reading test in China. Apart from other reasons, this may be because reading disorder is not regarded as a serious problem in China.

To see more details on the aspects of reading Chinese characters we get the following characteristics:

- 1) Configuration and phonology symptoms

Two sorts of questions concerning visual configuration and phonological structure of Chinese characters in the questionnaire revealed symptoms in these two aspects of Chinese script. From Table 3.3 and Table 3.4 and Figure 3.3 and Figure 3.4, we can see

the occurrence of these two kinds of symptoms.

Q5, Q6, Q7 and Q9 are concerned with the configuration aspect of Chinese characters. As we can see, all these symptoms happened in reported reading disorder pupils and other pupils who were not regarded as having reading disability.

The existence of these symptoms implies that there are some problems in reading Chinese characters with regard to their visual configurations.

Q3 and Q8 are concerned with the phonological aspect of Chinese characters. As we can see, these two symptoms happened in reported reading disorder pupils and other pupils who were not regarded as having reading disability.

The existence of these two symptoms implies that there are some problems in reading Chinese characters with regard to their phonology.

2) Common symptoms

Q10, Q11, Q12 and Q13 in the questionnaire are concerned with some common symptoms which usually come with developmental dyslexia of alphabetic languages. These symptoms were also revealed in this survey.

The existence of these symptoms reveal some common features relating to learning disability. However, as we can see from correlation analysis on these symptoms with reported reading disability, it is difficult to relate these features with reading disability in Chinese pupils, and this, on the other hand, implies again that reading disability for Chinese characters diagnosed in

the light of the common criteria might be different from what we have seen in alphabetic languages.

3) Sex, handedness, grade and reading disability

As we have seen from the results of this survey, there are some similar features between Chinese reported reading disorder pupils and developmental dyslexia of alphabetic languages in the aspects of distribution of dyslexia in sex, handedness and grade. In this survey, more boys were reported to have serious reading problems than girls; the ratio of reported reading disorder pupils is higher in left handed students than that in right handed students; and as the grade increases the ratio of reported reading disorder pupils decreases. These are similar to what happens in developmental dyslexia of alphabetic language.

4) Factors in reading problems

As the result of factor analysis on reported reading disorder pupils showed, there are two factors governing these reading phenomena. One factor reflects a problem in sensori-motor aspect, the other factor reflects a problem with spatial position. As the result of factor analysis on the pupils being surveyed showed, there are four factors governing the occurrence of symptoms in the population. Factor one probably reflects a problem in spatial position; factor two probably reflects a sensori-motor problem; factor three probably reflects a problem in MBD (Mild Brain Disfunction, a common syndrome in children); and factor four probably reflects a problem in orientation.

5.6. CONCLUSION

(1) The ratio of reading disorder pupils for Chinese characters revealed through the survey on 8106 pupils on grade 2 to 6 in China is quite low: 1.92%.

(2) Although the ratio of *reported reading disability* with Chinese characters is low, the percentages of pupils with problems in reading Pin-Yin are not so low. Moreover, pupils with Pin-Yin problems *are also reported to share some common features with developmental* dyslexia in alphabetic languages, such as: they both have the tendency to confuse the letters "b", "d", "p" and "q"; they both show differences in sex, in handedness, and in grades.

(3) The occurrence of other symptoms is also not low. It seems to be reasonable to distinguish developmental dyslexia in the light of common criteria from more general reading problems for Chinese learners.

(4) Symptoms with configuration aspect of Chinese characters are found to be common in both *reported reading disordered* pupils and other pupils. This happens because of the special features of Chinese characters and it reflects the script effects in reading disorders.

(5) Symptoms with phonological aspect of Chinese characters are also found in both reading disordered pupils and the other pupils. This indicates the importance of phonology in reading development even for learning Chinese characters.

CHAPTER 6

THEORETICAL CONSIDERATION ON READING CHINESE CHARACTERS

At the begining of this thesis, we have addressed a fundamental issues in reading Chinese characters: i.e. whether reading Chinese characters can be achieved by more than one route; and whether the routes involved in the reading process are independent of each other. In considering the special features of Chinese characters, we have also addressed the lateralization and developmental issues in reading this particular logographic system. Now we need to attempt answers to these theoretical questions.

6.1. Background

Since there is not much theoretical discussion on reading Chinese, we need first of all to turn our attention to the theory of reading alphabetic words. In fact, the models on reading alphabetic words provide us with a background for theoretical discussion on reading Chinese.

As we have seen in Chapter 1, many psychologists have now suggested the multi-route model as a theoretical framework for reading. There are different versions of this model, but the basic principles of them are the same: reading a word can be achieved by more than one route, and the routes involved are independent of each other. As for individual routes, there are different opinions from different multi-route models. However, in general, the following three routes have been most often suggested:

(1) a route from word to sound via a grapheme-phoneme conversion called the phonological route; and (2) a route from the whole word to the sound of the word called the direct route; and finally (3) a route from a word to its meaning then to its sound called the lexical route.

Studies on reading alphabetic words especially in clinical field have given evidence for the above three reading routes. Surface dyslexia has been used to demonstrate the phonological route in isolation; phonological dyslexia has been used to demonstrate the impairment of this phonological route; and deep dyslexia has been used to demonstrate the function of the lexical route in isolation.

With regard to the lateralisation issue, many studies on reading alphabetic words have shown that the left hemisphere is underlies reading in many experimental conditions.

As far as developmental dyslexia issue is concerned, one important fact that has attracted great attention is that phonological segmentation is important in the development of reading alphabetic words.

Given the above background in reading alphabetic words, we now turn to see what happens when reading Chinese characters. First of all, we have to tell what the differences between Chinese and alphabetic words are from a linguistic point of view.

Basically, Chinese characters differ from alphabetic words in the sense that they are a logographic system. As such a system, Chinese characters posses some distinctive configurational

properties which we do not find in alphabetic words. A Chinese character is not constructed by phonological units. There is no spelling to sound mechanism in it. As far as the phonological features of Chinese characters are concerned, we have seen that they are set up on the basis of a monosyllabic system. Because of this, one character equals one syllable. There is a direct relationship between character and syllable but not character and phoneme. In pictophonetic characters, the phonetic radical which is one of their components, represents the characters' sound to some extent. To be more informative, we have produced a statistical analysis of the phonological features of Chinese characters. 36 percent of the phonetics represent their character's sound correctly. 48 percent of the phonetics partially represent sound. 16 percent do not represent the sound at all. The homophone ratio of Chinese characters is 8. The ratio of determining meaning from a character's sound is 0.087. These figures indicate that getting sound is not as reliable a guide to meaning as in English.

Based on the theories of reading alphabetic words and the special features of Chinese characters, we can hypothesise a model of reading the Chinese script.

6.2. A possible model for reading Chinese characters

Since there are not many studies on reading Chinese characters, and my research is a preliminary exploration in this field, I can not go into the detailed components of the routes

involved in the reading processes. What I can propose here is only a basic framework of reading Chinese.

Considering the universal features of a written language and the function of phonetics in Chinese characters, I would suggest that there are the same three routes in reading them but organised somewhat differently, because of script effects (see figure 6.1).

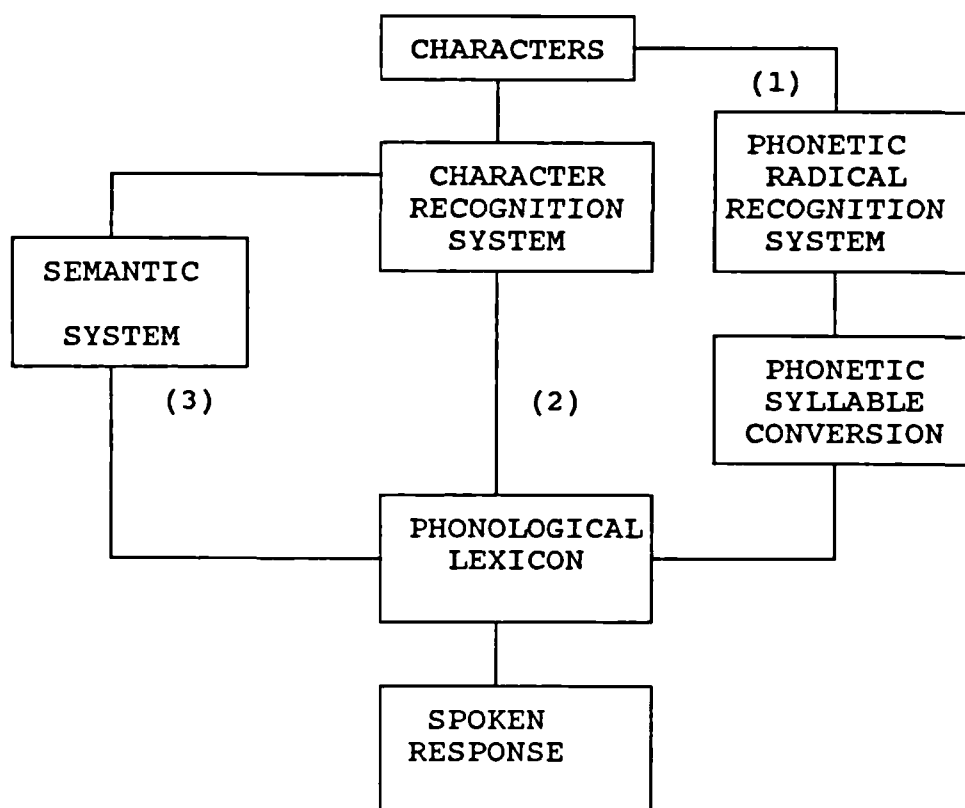


Figure 6.1. A model of reading Chinese characters

The diagram shown in Figure 6.1 illustrates these three routes. Route 1. Characters are read through a phonetic-syllable conversion mechanism. Pictophonetic characters can be read in this route while the phonetic radical of the characters is recognised in

the phonetic radical recognition system. (Note: when reading a pictophonetic character, the same character will be analysed as a whole character and a pictophonetic with a radical, in parallel). This route is the counterpart to the phonological route in reading alphabetic words. The difference is that here there is a phonetic to syllable conversion rather than a grapheme to phoneme one and it is on the basis of whole syllable rather than components of the sound. From the phonetic-syllable conversion system, information is sent to phonological lexicon where an appropriate output phonological item is obtained. An output phonological item is a syllable/morpheme. In other words, the output phonology for Chinese characters is not assembled from individual phonemes. Route 2. Characters are categorised by a visual recognition system, and then sent directly to the phonological lexicon system where an output phonological item is produced. This route is the equivalent to the route from the whole word directly to its sound in reading alphabetic words. Route 3. Characters are again categorised by the visual recognition system, and then transmitted to the semantic system. Here, the appropriate semantics can be found and sent to the phonological lexicon system where the phonological code is found. This route is parallel to the lexical route in reading alphabetic words.

If the above proposed reading process is correct, what would follow on is that normal Chinese readers could use each of the above three routes in their reading practice. Thus, by experimentation, we would be able to find evidence that shows

phonological recoding is automatically activated during the reading process. We would be able to find evidence which shows Chinese readers can use a phonetic-syllable route to pronounce pictophonetic characters, and when these characters are irregular ones, the readers may make some regularization errors. We would also be able to find evidence which shows the lexical route is mostly used by Chinese readers to get the character's meaning and sometime they make semantic errors under some circumstances. In the clinical field, I would predict that we would be able to find some Chinese dyslexic patients whose reading performances show these routes in impairment. We would expect that there are some cases in which one of the reading routes is blocked. We would also expect that there are some patients whose reading disability is similar to surface dyslexia, and that there are some patients whose dyslexic symptoms are *analogous* to deep dyslexia. However, in the light of the characteristics of Chinese characters, surface and deep dyslexia in Chinese patients might have some special features. Moreover, with regard to the visual properties of Chinese characters, I would predict that there will be some special features in reading Chinese characters relating to their configuration aspect. Thus, we may be able to see some special dyslexic symptoms in Chinese patients.

As far as the lateralisation is concerned, I would propose that it is connected with phonological process in reading, and as such it will appear no matter what kind of scripts we use. Thus, the left hemisphere advantage for reading alphabetic words is also

applicable to reading Chinese characters when there is a requirement for manipulating phonological information. Therefore, we would be able to find a right visual field-left hemisphere superiority whenever phonological manipulation is required in the experiments. We would expect that this left hemisphere advantage is also supported by clinical cases in which the left brain damage is dominant.

Concerning the developmental aspect of reading Chinese characters, I would suggest that there are less cases of developmental dyslexia in reading Chinese than in reading alphabetic words due to the fact that there is not the same demand for phonological segmentation skills, which are important in causing developmental dyslexia. However, there will be some other developmental problems due to the characteristics of Chinese characters. Therefore, we would be able to find a low rate of Chinese developmental dyslexia, but the problem in reading Pinyin can be as severe as that in reading alphabetic words. Moreover, an important factor in causing reading problems can be traced to the great demand for dealing with complex configurations of Chinese characters.

Can the above predicted model and features in reading Chinese characters be substantiated from my studies?

6.3. Summary of the results of my studies

6.3.1. Phonological recoding in reading Chinese characters

Since the basis for the phonological route is the

phonological recoding, the very first thing I need to do in my research is to give an answer to this issue. More precisely, the question to be answered is whether phonological recoding is an automatic process in reading Chinese? The answer to this question is given by experiment One which showed homophone effect in recognising characters. In that experiment, phonological recoding was revealed to be automatic. This finding is consistent with many other studies (c.f. Tzeng et al. 1977).

However, although the phonological recoding is an automatic process, it is not an obligatory step in reaching the meaning of the characters. This has been demonstrated in some clinical cases where the patients could not get the sound of the character but nevertheless they could get the meaning (patient LYM, LWY, and ZZG). Moreover, phonological recoding seems not to be an important process in achieving the meaning of the characters. This can be demonstrated by the fact that Chinese surface dyslexia did not have homophone confusion. We will discuss this later.

6.3.2. Are there different routes to a character's sound?

For this question, first of all, we can give a positive answer from a linguistic point of view. We have shown that Chinese characters can be divided into two structural types. One is the single-graph character, the other is the combination-form character. Most of the combination-form characters have a sound radical (phonetic) and a meaning radical (signific) as their structural components. Since single-graph characters cannot be further divided into smaller pronounceable units, the sound of a

single-graph character is represented by the whole character itself. Therefore, the phonological route in reading a single-graph character is characterised by a whole character to a whole sound manner. However, in the case of the combination-form characters, the situation is different. Since the phonetic in a combination-form character has the function of representing the sound of a character, and it can be pronounced, therefore the phonological route in reading a combination-form character can be formed in two ways: one is the whole character to the whole sound; the other is the phonetic to the sound.

Evidence for the existence of the whole character to the whole sound is quite obvious since the single-graph characters can be read aloud by any normal Chinese readers. Evidence for the existence of the phonetic to the sound has been found in the case of Chinese surface dyslexia in which the patients were reading aloud the combination-form characters by pronouncing the phonetic and thus made many regularization errors when the characters were irregular ones.

On the surface, the route from the phonetic to the sound looks like the phonological route in reading alphabetic languages where a grapheme-phoneme conversion (GPC) exists, but actually they are quite different. The GPC route in reading alphabetic languages is set up on a spelling to sound basis, but moving from the phonetic to sound in reading Chinese characters has nothing to do with spelling because there is no spelling to sound construction in Chinese characters. In fact, the route from the phonetic to sound

is also set up on the basis of the whole character to the whole sound, because the phonetic is itself a character too.

6.3.3. Can the route to meaning be independent of the route(s) to sound?

The results of my research have given positive answers to this question both from experimental and clinical studies.

In experiment Five, we have found that meaning relationships unlike sound relationships do not show a visual field effect. This implies that the brain works differently when reading for meaning and reading for sound. It is obvious that if different hemisphere mechanisms are involved, the route to meaning and the route to sound should have different neural basis, at least in part, and thus these two routes can be independent from each other.

In experiment Six, we have found some normal subjects who made some semantic errors (8 out of 12 made semantic errors). This indicates that Chinese readers sometimes use the lexical route exclusively when under an experimental condition, i.e. speeded reading. It was also found in the experiment that there were more Cantonese speakers who tended to make semantic errors than Mandarin speakers (all Cantonese speakers made semantic errors, only half of Mandarin speakers made the same errors). Moreover, Cantonese speakers were found to make more semantic errors than their counterparts (the amount of semantic errors made by Cantonese subjects being from 2 to 6, whilst for Mandarin subjects it was from 1 to 3). The difference between Cantonese subjects and Mandarin subjects is that the phonological information for reading

the characters used in the experiment was less sufficient in the former than in the latter. This further indicates that the lexical route was more often used by Cantonese subjects in isolation.

Stronger evidence came from the clinical case studies.

In order to sufficiently demonstrate that the route to meaning is independent of the route(s) to sound, we need to find a double dissociation between these routes. This double dissociation has been found in some clinical cases: (1) the patient (QXS) has symptoms in which he could not match characters with pictures but could pronounce them correctly; and (2) patients (LYM, LWY, and ZZG) have symptoms in which they could not pronounce the characters but could match them with pictures correctly. The former symptoms happen when the route from script to meaning is damaged while the route from script to sound remains intact; the later symptoms happen when the route from script to sound is damaged while the route from script to meaning remains intact.

6.3.4. Access to characters' meaning

One important aspect in the issue of the routes involved in reading Chinese characters is that the phonological route does not constitute the main access to the meaning of the characters. It is the lexical route that takes the main responsibility for arriving at the meaning of the characters as the case studies implied.

In the case of surface dyslexia in reading alphabetic languages, one important symptom is that some patients understand the words as how they pronounce them, and thus homophone confusion occurs in reading tests (Patterson, Marshall and Coltheart, 1985).

However, in the case of surface dyslexia in reading Chinese characters, there is no homophone confusion at all. Although Chinese surface dyslexic patients do make regularization errors when they are reading Chinese irregular characters, they nevertheless can understand what the words really mean. This is an important phenomenon, because it indicates that reaching the phonology of the characters does not pave the way to reaching the meaning of the characters.

In cases where associative dyslexic symptom occur, reaching the meaning of the characters through the lexical route but not the phonological route is also emphasised. In such cases, although the patients (LSH, LQF and LSJ) cannot pronounce the whole characters (they can only pronounce the components of the associative characters), they nevertheless can reach the correct meaning of the whole characters.

Moreover, the survey of the developmental disorder of reading Chinese characters has also provided evidence for the above argument. In the survey, a notable fact has been revealed that although some pupils have a problem in dealing with the phonological aspect of the Chinese characters, and some of them even have symptoms similar to what happens in developmental dyslexia in reading alphabetic languages, they nevertheless do not have a severe problem in reading in the general sense. Statistics show that there is no strong correlation between problems in dealing with the phonological aspect of the Chinese characters and the occurrence of the reading disability. The explanation for this

notable phenomenon may lie in the fact that reading could be achieved mainly by a non-phonological route to meaning. In other words, the phonological recoding seems not to be a crucial or important process in reading Chinese characters.

A distinct feature of the multi-route process in reading Chinese characters is that the phonological route does not constitute an efficient access to the meaning. This feature is determined by the characteristics of the phonological structure of Chinese. As we have seen from Chapter 2, a semantic uncertainty exists in the way of getting meaning from the sound. There is a low ratio of determining meaning by a single Chinese character's sound (0.087), but there is a high ratio of homophones (0.81), and high degree of homophones (7.85) in Chinese language. Such an uncertainty actually precludes efficiency in the phonological route to meaning.

6.3.5. On the configuration aspect of reading Chinese characters and the features associated with reading associative character and compound words

The results of normal reading experiments show that there is a phenomenon which reflects the structure of Chinese characters. The studies of clinical cases reveal that there are some acquired dyslexic symptoms which are mainly manifested in relation to the properties of the form of Chinese characters, such as associative dyslexic symptoms. Moreover, there are also some developmental reading symptoms connected with problems in manipulating the form of the script.

To sum up the results, we can see the following features in the configuration aspect of reading Chinese characters.

Firstly, we have found that there is a perceptual separability in dealing with the configuration of Chinese characters. As we have seen from the analysis of Chinese characters, the configurations of Chinese characters are manifested in separable hierarchical structures which give rise to the basis for the perceptual separability. Clinical acquired dyslexic cases have further provided some symptoms which demonstrate that patients sometimes read combination-form characters in a separate manner. Such as: surface dyslexia, associative dyslexia, and compound dyslexia. A developmental reading disorder survey has shown that there is a symptom in which pupils have difficulty in putting radicals in correct positions.

Following the perceptual separability and integration in dealing with the configuration of Chinese characters, we would naturally ask the question: what is the the basic unit in reading Chinese characters? Such a unit has configuration unity and phonological unity as well. Such a unit is basic in reading Chinese characters.

The results show that such a unit is the radical. It is the radical that functions as the perceptual unit in the experiment of normal subjects. It is the radical that surface dyslexic patients read aloud. It is also the radical that associative dyslexic patients manipulate too. And it is again the radical that is being wrongly positioned in developmental reading disorder symptoms.

Moreover, evidence from the studies of acquired dyslexic patients has shown that the basic recognized pattern of in the reading of Chinese characters is the radical. In an overlapped character test which used radicals as the overlapping characters, patients had no difficulty finding the individual characters (i.e. radicals). In a test of filling in missing strokes in which the characters being used are also the radicals, patients had no difficulty completing the task. What is more significant is that these two tests can be completed by patients no matter what kind of reading difficulties they had. This means that the basic pattern of Chinese characters has a comparatively strong unity which is resistant to damage. Such a fixed pattern is suitable to serve as a basic unit in the reading of Chinese characters.

The last question in the configuration aspect of reading Chinese characters is: what is the significance of the configuration in relation to the routes involved in reading Chinese? The answer to this question is that the abundant variety of the visual features in Chinese characters make the route from script to meaning more important for Chinese readers. The fact that Chinese surface dyslexic patients do not have homophone confusion indicates this importance, and implies that the configuration of Chinese characters has a critical position in relation to their meaning. Moreover, the low ratio of developmental dyslexia revealed in my survey also implies that reading Chinese can be effeciently achieved by the route from script to meaning.

6.3.6. On Lateralisation

In clinical case studies, the main damage to all of the patients was found to be in their left hemisphere, except for one boy where the damage was found in the right hemisphere. All of these patients were right handed. This fact indicates the importance of the left hemisphere in reading disability. This is consistent with the studies of acquired dyslexia of alphabetic languages and also consistent with some other research on acquired dyslexia of reading Chinese characters (Dejerine 1891, 1892; Lyman, et. al. 1938; Tang, 1978; etc.). Thus, it gives further evidence for the view that the left hemisphere is also dominant in reading Chinese characters.

In experimental studies of reading Chinese characters, the findings for lateralization is not as clear as that in clinical case studies.

The following interesting findings are the result of the lateralization experiments: (1) in the RECOGNITION experiment, no visual field effect was found; (2) in the ANTONYM experiment, no visual field effect was found; while, (3) in the NAMING experiment, a right visual field advantage was found; and (4) In the HOMOPHONE experiment, a right visual field advantage was found again.

These experimental findings do not support the idea that the left hemisphere is dominant for all aspects of the language function. As the experiments show, in lexical decision and in antonym judgement there are no visual field differences. However, these experimental findings suggest that the left hemisphere is

lateralized for the phonological function. As we can see, when the manipulation of the phonological information is required in reading tasks, the visual field differences characterising the advantages of the left hemisphere will appear.

In considering these, I would like to say that the clinical and experimental findings are not contradictory to each other, rather they are consistent in the sense that the left hemisphere is dominant in the main language function, i. e. phonological activity. One important factor in acquired dyslexia studies we need to pay attention to is that the main indicator for acquired dyslexia is reading aloud, and this is obviously a phonological activity. At this point, it would be reasonable to say that acquired dyslexia is usually manifested when the phonological process in reading is impaired. Therefore, the lateralization in the clinical studies also indicates the dominant function of the left hemisphere in manipulating the phonological information. It is worth noting that some patients, who were unable to name characters, could nevertheless match them to pictures, perhaps indicates spared right hemisphere function.

Considering the fact that there are evident differences between Chinese characters and alphabetic words, I could say that the finding of a similar important role played by the left hemisphere in reading Chinese characters has significant implications for the nature of the reading process in general.

6.3.7. On the developmental dyslexia issue

The survey I have done on pupils in Chinese elementary

schools shows a quite low ratio (1.92%) of developmental dyslexia. It is surprising that although there are significant problems with configuration in reading the characters, the reading performance (mainly comprehension) seems not to be affected seriously. This seems to be a peculiar feature in reading logographic systems. However, we should note that this low ratio of developmental dyslexia in Chinese pupils is focussed on the aspect of reading Chinese script. If we look into the condition of reading Chinese alphabetic Pinyin, we find that the ratio of reading problems is not that low (6.1 % of pupils being surveyed were regarded to be unable to correctly read and write out Pinyin for new characters. 5.3 % of pupils were regarded to have Pinyin letter confusion), rather it is similar to that in reading alphabetic words. In addition, the symptoms in reading Chinese Pinyin share similar features with that in reading alphabetic words: Chinese pupils also feel confused when they come across similar letters in Pinyin (i.e. p with q and b with d). This gives us a good indication of the role played by the script effect in developmental dyslexia. The study of this developmental dyslexia facilitates the research on experimental and clinical aspects of reading Chinese characters, thus helping our understanding of reading Chinese characters. Nevertheless, we should note that this survey of developmental dyslexia on reading Chinese is only a preliminary attempt; and since there has been no such survey conducted in this field on Mainland China, we could not expect to get much information with regard to the routes involved in reading Chinese. What we have got

here is indirect evidence which shows the importance of the phonological aspect in causing developmental dyslexia and the dominance of using the non phonological route in reading Chinese.

6.4. Conclusion

Based on the above considerations, a general picture of reading Chinese characters can be drawn as follows:

The basic framework is a multi-route process. There are three different routes involved in reading Chinese characters:

(1). A route from character to sound via phonetic-syllable conversion. This route is equivalent to the phonological route in reading alphabetic words where a grapheme-phoneme conversion is employed. However, unlike reading alphabetic words, this route is not used as an efficient access to a character's meaning.

(2). A route from character to sound without a phonetic-syllable conversion. This is a whole character to whole sound route and it is the only route from character to sound without semantic in reading single-graph characters since they do not have a phonetic.

(3). A lexical route from character to meaning. This route is more developed in Chinese reading than in alphabetic reading, and it is the dominant route for reaching the meaning of Chinese characters.

These different routes are independent of each other.

Apart from the multi-route nature of reading Chinese

characters (which are basically compatible with reading alphabetic words), there are some other features which are characterised by reading this logographic system. These special features are mostly related to the configuration aspect of Chinese characters: the basic recognition unit of Chinese is the radical; there is a separability in reading combination-form-characters; and finally, there are some special symptoms relating to these special features (associative and compound dyslexia).

With regard to hemisphere function, reading Chinese characters are lateralised by phonological manipulation.

Finally, in the developmental aspect, Chinese pupils are not severely affected by a reading disability when seen in the light of the criteria used for the definition of developmental dyslexia; yet, there are some other reading problems relating to the visual-spatial aspect of the script.

6.5. Directions for future research

What I have done so far is only the beginning of my research into a few major issues concerning the reading of Chinese characters. Much more work needs to be done. Below there follows an outline of my intended future studies in this area.

6.5.1. In the experimental field:

(1). More restricted experiments on phonological recoding in reading Chinese characters

In the discussion of my experiment on phonological recoding (the picture-character matching experiment), I have addressed the problem of successive presentation of stimuli. To solve this

problem I should carry out such experiment again but with simultaneous presentation of stimuli, to ensure that phonological recoding is not a task-specific strategy.

(2). More experiments on the use of the phonetic-syllable route

In my normal subjects' speed reading experiment, one finding is that the regularization errors occur when the subjects were reading irregular Chinese characters. In my clinical case studies, Chinese surface dyslexia was found. These findings demonstrate the phonetic-syllable route in reading Chinese. A further question raised here is: under what circumstances is this route usually used?

To answer this question, I need to do more experiments on the regularization aspect in reading different kinds of pictophonetic characters.

There are some pictophonetic characters which have a consistent phonetic; and there are some pictophonetic characters which have an inconsistent phonetic. It may be that radicals are used to derive pronunciation only when they are consistent. By using these different kinds of regular and irregular pictophonetic characters to test the regularization effect in reading Chinese, we might be able to find the answer to the above question.

(3). More lateralization experiments on the phonological process

My experiments on the laterilisation aspect in reading Chinese characters show evidence of the connection between the

phonological process and the laterisation function of the brain. This relationship should be further explored in more experiments.

6.5.2. In the clinical field:

(1). More detailed examination of surface dyslexia

In line with further experimental study, a high frequency and low frequency irregular character test on Chinese surface dyslexic patients should be carried out. This test will enable us to see under what circumstances a Chinese reader will use the phonetic-syllable route. Moreover, I need to see more details of homophone reading in surface dyslexia. One method of addressing this task is to use two different kinds of homophonic characters as test material (the same as those to be used in further normal experiments).

(2). More detailed examination on deep dyslexia

In contrast to further study on surface dyslexia, I also need to do more detailed research on Chinese deep dyslexia.

As we have seen in this preliminary clinical study, Chinese deep dyslexic patients have some special features which are different from that in alphabetic readers. One of these features is that larger neuroanatomical damage seems not to be necessary. This indicates that there might be some different mechanism underlying these symptoms, which we badly need to find out.

(3). The lexical route test

It is obvious that a study of Chinese acquired dyslexia can provide us with a good chance to observe the function of the lexical route in reading. We have seen that there are different

kinds of semantic errors in reading Chinese characters which exhibit something of this lexical route. We have also seen that Chinese surface dyslexics can use this lexical route to get the correct meaning from the characters which they mispronounce. Following on from this, we need to take a more detailed look at the lexical route.

6.5.3. In the developmental field:

(1). What I have done so far in this field is only a pilot survey. I will need to advance my study by conducting a further survey on the ratio of developmental dyslexia by a new questionnaire based on the one I have already used. However, I need to adapt the survey to the individual, i.e. a questionnaire for each individual subject, an IQ test for each individual subject and finally individual tests for visual and phonological aspects.

(2). I will need to carry out a Pinyin developmental dyslexia survey. It is obvious that Pinyin is the only suitable counterpart in Chinese for alphabetic language. Therefore, a Pinyin developmental dyslexia survey will provide us with compatible evidence for a universal reading problem.

In short, there is much more research to be done in further developing the theory of reading Chinese characters and also for the contribution to a universal reading model.

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APPENDIX A. TABLES OF EXPERIMENTAL STUDIES

(1). EXPERIMENT ONE

Table 1. Subjects' mean R.T. (correct) in three different tasks

Subjects	Sex	P-C (R)	P-C (H)	P-C (N)
1	M	61.7895	71.7368	69.7619
2	M	54.4000	63.4090	58.6500
3	M	60.6000	68.0000	64.4286
4	M	94.3500	118.5000	101.6360
5	M	51.7273	54.0000	53.1364
6	M	47.0000	50.3500	51.9500
7	M	47.4286	54.4500	51.0455
8	M	42.1579	45.7600	43.5455
9	M	70.5556	69.2380	68.9545
10	M	68.7143	72.9048	67.8636
11	F	46.4545	53.4545	51.2500
12	F	73.8667	89.5000	81.7857
13	F	51.5230	60.8888	52.9545
14	F	53.8230	55.1364	55.2381
15	F	52.0000	67.8095	61.3000
16	F	72.2105	69.1905	68.1429
17	F	58.8947	62.4211	63.2857
18	F	58.0000	73.3330	67.9048
19	F	61.4762	69.3500	59.0952
20	F	54.3000	58.2000	61.3330

In table 1. each cell represents the mean R.T. for corresponding task which is the mean of each experiment trial, i. e. Picture-character (R) or Picture-character (H) or Picture-character performance. These mean R.T.(s) were calculated from subjects' correct answers.

Table 2. One-way ANOVA with repeat measures for experiment one (R.T. correct)

DUE	DF	SSQ	MSQ	F
SUBJ	19	10204.12	537.06	
A	2	535.58	267.79	20.10
ERR	38	506.80	13.34	
TOT	59	11246.50		

Using one-way analysis of variance with repeat measures, comparing MAT.RT(A), MAT.RT(C) and MAT.RT(B), the differences among them, confirmed statistically, were quite obvious. $F = 20.10$, this is very significant, $P < 0.001$.

(2). EXPERIMENT TWO
Table 1. Subjects' mean RT in experiment two

Sub.	R		N		P	
	LV	RV	LV	RV	LV	RV
1	1.39900	1.44789	1.33000	1.31316	1.46200	1.57684
2	0.87700	0.96300	0.97895	0.89300	0.84800	1.05900
3	1.13800	1.15900	1.11300	1.21947	1.07368	1.15632
4	1.39579	1.71800	1.33700	1.39900	1.53300	1.79700
5	0.66000	0.71100	0.81400	0.82400	0.88900	0.87500
6	1.03100	1.07200	1.11400	0.96500	1.25333	1.25316
7	0.89211	0.87500	0.85900	0.95000	0.90500	0.92000
8	1.24200	1.14900	1.29000	1.28100	1.46684	1.35700
9	0.85900	1.18700	1.19700	1.31100	1.45600	1.22500
10	1.04526	1.10300	0.97800	1.04000	1.10700	1.18000
11	0.90526	1.00300	1.06700	1.15200	1.14900	1.21500
12	0.98700	0.81100	0.97500	0.98600	0.93100	1.06211
13	0.78900	0.82400	0.79737	0.77600	0.90400	0.86900
14	0.96500	0.95200	1.07200	0.98900	1.31000	1.07700
15	1.29526	1.19632	1.31200	1.51200	1.52789	1.62579
16	0.75900	0.82526	0.71600	0.75500	0.89800	0.89900
17	0.75700	0.68600	0.84200	0.82300	0.85400	0.79700
18	0.88300	0.84200	0.95700	1.09300	1.36950	0.14763
19	0.77600	0.83200	0.69200	0.73600	0.73105	0.90000
20	1.21526	1.05700	1.09800	1.19400	1.15500	1.23100
21	0.81500	0.80737	0.79100	0.79800	0.87421	0.81500
22	1.04100	0.90500	0.88500	0.97000	1.12800	1.15611

23	0.75800	0.76000	0.78200	0.81000	0.79900	0.78722
24	1.23100	1.18600	0.87900	1.22700	1.15800	1.23667

In the table each cell is the mean reaction time of an individual subject for distinction among real Chinese characters, non-characters and pseudo-characters, either presented in the or right visual field.

Table 2. Rate of mistake in either visual fields when recognizing real, or pseudo, or non-characters

Sub.	R		N		P	
	LV	RV	LV	RV	LV	RV
1	0.20	0.15	0.15	0.15	0.26	0.32
2	0.25	0.26	0.15	0.00	0.20	0.20
3	0.00	0.15	0.10	0.25	0.60	0.65
4	0.36	0.25	0.10	0.10	0.60	0.20
5	0.05	0.05	0.00	0.05	0.11	0.15
6	0.20	0.15	0.15	0.10	0.30	0.25
7	0.20	0.10	0.35	0.10	0.40	0.37
8	0.11	0.10	0.20	0.45	0.45	0.85
9	0.37	0.20	0.20	0.05	0.20	0.30
10	0.05	0.15	0.10	0.30	0.60	0.80
11	0.10	0.10	0.21	0.10	0.40	0.50
12	0.37	0.05	0.55	0.50	0.45	0.44
13	0.20	0.11	0.00	0.05	0.35	0.40
14	0.00	0.00	0.15	0.05	0.58	0.65
15	0.05	0.15	0.15	0.15	0.35	0.50
16	0.05	0.50	0.15	0.37	0.60	0.50

17	0.15	0.10	0.20	0.25	0.50	0.47
18	0.20	0.05	0.10	0.15	0.40	0.60
19	0.15	0.16	0.20	0.05	0.47	0.65
20	0.20	0.15	0.00	0.10	0.20	0.28
21	0.10	0.30	0.15	0.20	0.20	0.50
22	0.20	0.15	0.10	0.15	0.30	0.61
23	0.21	0.25	0.00	0.10	0.35	0.05
24	0.25	0.15	0.20	0.05	0.47	0.30

In the table each cell is a rate of wrong reactions of an individual subject for recognition of real Chinese characters or non-characters or pseudo-characters, either presented in the left visual field or in the right visual field.

Table 3. Three way anova with repeat measure for RT in LV of experiment two

DUE	DF	SSQ	MSQ	F
A	1	0.063291	0.063291	0.48176
B	1	0.312261	0.312261	2.37690
A*B	1	0.000970	0.000970	0.000739
ERR	20	2.627462	0.131373	
C	2	0.248256	0.124128	14.23346
A*C	2	0.018133	0.009066	1.03961
B*C	2	0.027321	0.013660	1.56642
A*B*C	2	0.079385	0.039693	4.55146
ERR	40	0.348835	0.008721	
TOT	71	3.725914		

Table 4. Three way anova with repeat measure for RT in RV of experiment two

DUE	DF	SSQ	MSQ	F
A	1	0.004599	0.004599	0.02646
B	1	0.762915	0.762915	4.38889
A*B	1	0.094918	0.094918	0.54604
ERR	20	3.476574	0.173829	
C	2	0.124647	0.062324	3.22786
A*C	2	0.003358	0.001679	0.08696
B*C	2	0.047407	0.023704	1.22766
A*B*C	2	0.088622	0.044311	2.29495
ERR	40	0.772319	0.019308	
TOT	71	5.375359		

In the above tables, A is the factor of right hand vs left hand; B is the factor of male vs female; C is the factor of stimuli.

The multi-way ANOVA shows there is a significant difference among RT for different stimuli in the left visual field, $F = 14.23346$ $P < 0.001$.

Table 5. Three way anova with repeat measure for Rate of Accuracy in LV of experiment two

DUE	DF	SSQ	MSQ	F
A	1	0.016806	0.016806	0.98950
B	1	0.018689	0.018689	1.10039
A*B	1	0.053356	0.053356	3.14154
ERR	20	0.339678	0.016984	
C	2	0.842978	0.421489	31.02669

A*C	2	0.034411	0.017206	1.26654
B*C	2	0.024211	0.012106	0.89112
A*B*C	2	0.059744	0.029872	2.19896
ERR	40	0.543389	0.013585	
TOT	71	1.933261		

Table 6. Three way anova with reapeat measure for Rate of Accuracy in RV of experiment two

DUE	DF	SSQ	MSQ	F
A	1	0.019339	0.019339	0.68048
B	1	0.001800	0.001800	0.06334
A*B	1	0.115200	0.115200	4.05356
ERR	20	0.568389	0.028419	
C	2	1.261911	0.630956	35.56794
A*C	2	0.014478	0.007239	0.40807
B*C	2	0.022800	0.011400	0.64264
A*B*C	2	0.165233	0.082617	4.65723
ERR	40	0.709578	0.017739	
TOT	71	2.878728		

In the above tables, A is the factor of right hand vs left hand; B is the factor of male vs female; and C is the factor of stimuli.

This multi-way ANOVA shows there is a significant difference among the rate of accuracy for different stimuli either in the left visual field or in the right visual field.

In the left visual field, $F = 31.02669$. $P < 0.001$.

In the right visual field, $F = 35.56794$. $P < 0.001$.

(3). EXPERIMENT THREE
Table 1. Subjects' mean naming reaction time

Subjects	LV	RV
1	0.8055	0.8165
2	0.6312	0.6068
3	0.7637	0.7368
4	0.5415	0.5153
5	0.7915	0.7350
6	0.6385	0.5475
7	0.8865	0.9855
8	0.7035	0.6900
9	0.7060	0.7050
10	0.6865	0.5532
11	0.7495	0.6816
12	0.7060	0.6505
13	0.8900	0.8755
14	0.7615	0.7250
15	0.4850	0.4830
16	0.5620	0.5265
17	0.7230	0.7089
18	0.7244	0.6015
19	0.7205	0.6205
20	0.7985	0.7165
21	0.7410	0.7165
22	0.6605	0.6150

23	0.7025	0.6905
24	0.6870	0.6495

In the table each cell is a mean RT of either left or right visual field of an individual subject.

Table 2. The accuracy of naming test in either fields

Subjects	LV	RV
1	0.20	0.05
2	0.05	0.10
3	0.10	0.00
4	0.05	0.00
5	0.15	0.05
6	0.05	0.05
7	0.10	0.20
8	0.00	0.05
9	0.05	0.10
10	0.15	0.05
11	0.15	0.15
12	0.25	0.15
13	0.15	0.10
14	0.05	0.00
15	0.05	0.05
16	0.00	0.05

17	0.10	0.10
18	0.10	0.00
19	0.20	0.10
20	0.00	0.05
21	0.15	0.05
22	0.20	0.10
23	0.20	0.05
24	0.15	0.05

In the table each cell represents the rate of accuracy in the naming tests either in left visual field or in the right visual field.

(4). EXPERIMENT FOUR
Table 1. Subjects' mean reaction time

Subjects	LV	RV
1	0.877	0.955
2	1.397	1.394
3	0.970	0.883
4	0.741	0.690
5	1.190	1.260
6	0.947	0.884
7	0.705	0.673
8	0.848	0.824
9	1.122	1.109
10	0.767	0.746
11	1.019	0.922
12	1.287	1.242
13	1.231	1.134
14	0.766	0.714
15	0.722	0.669
16	0.692	0.646
17	0.930	0.910
18	1.151	0.926
19	0.793	0.772
20	0.938	1.014
21	0.596	0.604
22	1.036	0.908

23	0.645	0.633
24	0.978	0.914

In the table each cell is an average RT for judging homophone pairs by each subject.

Table 2. Accuracy of each subject's performance for judging homophone pairs in either visual field

Subjects	LV	RV
1	0.20	0.20
2	0.15	0.20
3	0.10	0.10
4	0.20	0.15
5	0.10	0.15
6	0.30	0.10
7	0.15	0.10
8	0.20	0.20
9	0.20	0.10
10	0.05	0.10
11	0.00	0.00
12	0.00	0.10
13	0.10	0.05
14	0.20	0.15
15	0.35	0.15
16	0.10	0.10
17	0.35	0.30
18	0.20	0.25

19	0.15	0.15
20	0.15	0.00
21	0.15	0.10
22	0.10	0.10
23	0.20	0.05
24	0.10	0.15

In this table each cell gives the average accuracy of each subject's performance in judging homophone pairs in either visual field.

(5). EXPERIMENT FIVE
Table 1. Subjects' mean reaction time

Subjects	LV	RV
1	0.579	0.535
2	0.523	0.526
3	0.687	0.659
4	0.666	0.637
5	0.750	0.694
6	0.592	0.553
7	0.723	0.774
8	0.634	0.634
9	0.710	0.661
10	0.595	0.597
11	0.610	0.687
12	0.663	0.652
13	0.691	0.703
14	0.753	0.755
15	0.514	0.506
16	0.735	0.734
17	0.596	0.589
18	0.665	0.657
19	0.627	0.594
20	0.564	0.594
21	0.781	0.746
22	0.649	0.650

23	0.682	0.728
24	0.576	0.562

In the table each cell represents the average RT of an individual subject when judging antonym pairs in either visual field.

Table 2. Accuracy of judging antonyms by each subject

Subjects	LV	RV
1	0.10	0.05
2	0.15	0.15
3	0.10	0.10
4	0.10	0.05
5	0.20	0.10
6	0.10	0.15
7	0.35	0.25
8	0.05	0.00
9	0.00	0.05
10	0.05	0.35
11	0.05	0.20
12	0.15	0.05
13	0.10	0.05
14	0.25	0.20
15	0.00	0.05
16	0.20	0.20
17	0.05	0.05

18	0.05	0.00
19	0.20	0.15
20	0.05	0.10
21	0.00	0.00
22	0.10	0.15
23	0.00	0.05
24	0.15	0.10

In the table each cell represents the average accuracy of judging antonym pairs by each subject.

APPENDIX B. TABLES OF DEVELOPMENTAL DYSLEXIA STUDIES

TABLE 1. CORRELATION MATRIX OF DEVELOPMENTAL DYSLEXIA

	MALE	FEMALE	LEFTHAND	Q1	Q2	Q3	Q4	Q5	Q6	Q7a	Q7b
MALE	1.000										
FEMALE	-1.000	1.000									
LEFTHAND	-0.130	0.130	1.000								
Q1	0.012	-0.012	-0.013	1.000							
Q2	0.099	-0.099	-0.063	0.590	1.000						
Q3	0.083	-0.083	-0.147	0.698	0.432	1.000					
Q4	0.012	-0.012	-0.121	0.511	0.426	0.636	1.000				
Q5	0.091	-0.091	0.005	0.523	0.414	0.411	0.365	1.000			
Q6	0.042	-0.042	-0.087	0.340	0.347	0.240	0.288	0.374	1.000		
Q7a	0.070	-0.070	-0.025	0.571	0.391	0.533	0.507	0.416	0.269	1.000	
Q7b	0.001	-0.001	-0.036	0.590	0.426	0.369	0.310	0.447	0.346	0.486	1.000
Q8	-0.008	0.008	-0.095	0.605	0.339	0.558	0.481	0.411	0.240	0.563	0.436
Q9	-0.082	0.082	0.039	0.550	0.413	0.528	0.429	0.373	0.263	0.478	0.455
Q10	0.140	-0.140	-0.119	0.530	0.424	0.477	0.410	0.358	0.301	0.310	0.341
Q11	0.073	-0.073	-0.005	0.448	0.381	0.303	0.486	0.308	0.291	0.382	0.415
Q12	0.266	-0.266	-0.091	0.287	0.297	0.384	0.323	0.287	0.128	0.328	0.259
Q13	-0.041	0.041	-0.080	0.437	0.374	0.501	0.474	0.275	0.147	0.300	0.294
GRAD2	0.030	-0.030	-0.074	0.133	-0.018	-0.003	0.101	-0.080	0.172	0.041	0.014
GRAD3	0.001	-0.001	-0.036	-0.040	0.038	-0.063	0.030	0.066	-0.103	0.007	0.022
GRAD4	-0.052	0.052	0.048	-0.067	-0.098	-0.010	0.007	0.061	-0.025	-0.122	0.067
GRAD5	0.046	-0.046	-0.010	0.130	0.062	0.251	0.017	0.023	0.040	0.182	0.077
GRAD6	-0.033	0.033	0.098	-0.197	0.021	-0.190	-0.197	-0.070	-0.119	-0.127	-0.208

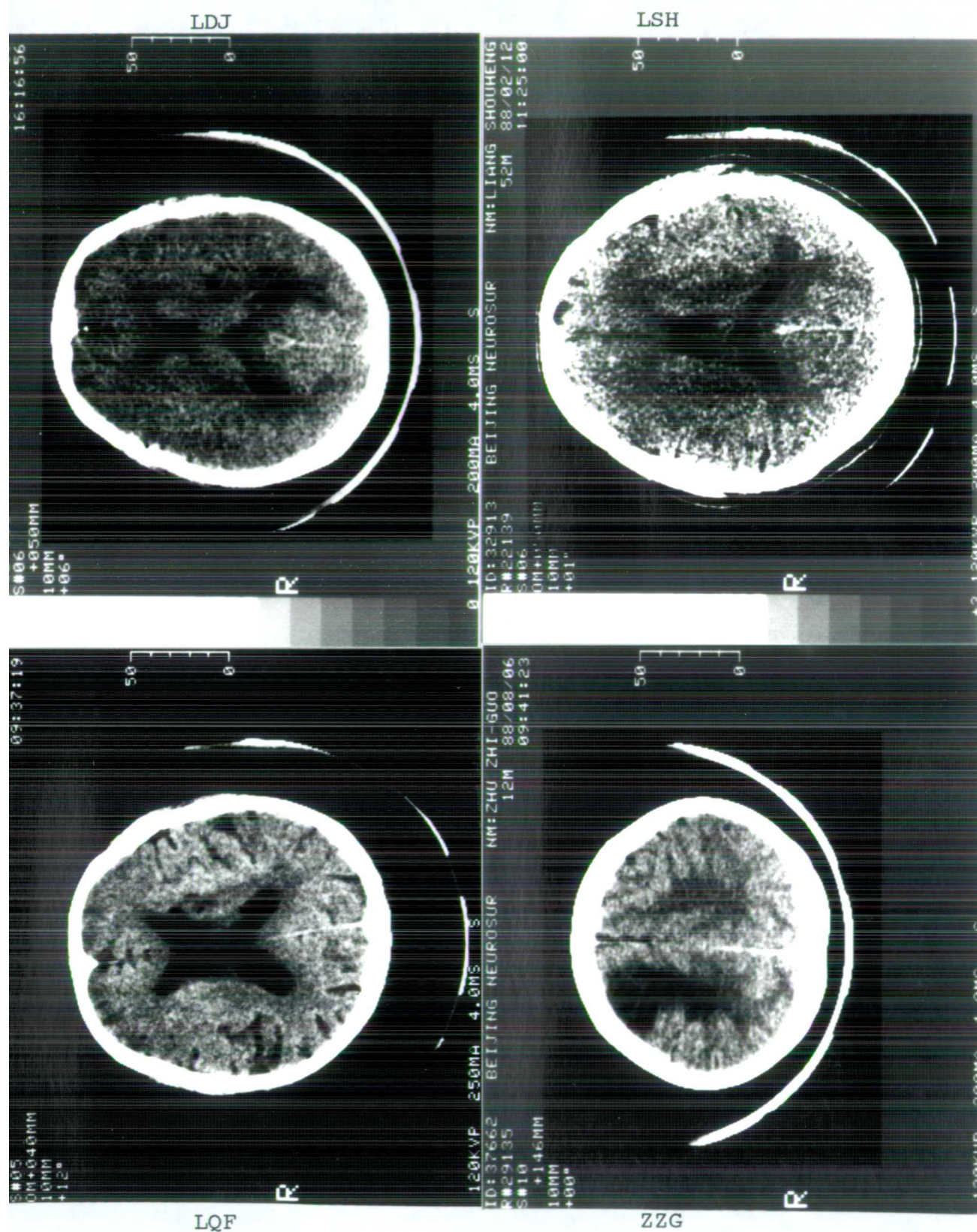
	Q8	Q9	Q10	Q11	Q12	Q13	GRAD2	GRAD3	GRAD4	GRAD5	GRAD6
MALE											
FEMALE											
LEFTHAND											
Q1											
Q2											
Q3											
Q4											
Q5											
Q6											
Q7a											
Q7b											
Q8	1.000										
Q9	0.499	1.000									
Q10	0.420	0.499	1.000								
Q11	0.303	0.230	0.392	1.000							
Q12	0.216	0.308	0.454	0.344	1.000						
Q13	0.327	0.389	0.339	0.164	0.185	1.000					
GRAD2	0.088	0.074	0.294	0.240	-0.046	0.056	1.000				
GRAD3	0.037	0.098	-0.014	0.046	0.107	-0.021	-0.331	1.000			
GRAD4	0.025	-0.111	-0.157	-0.132	-0.005	-0.024	-0.300	-0.252	1.000		
GRAD5	0.037	0.074	-0.008	-0.082	0.003	0.111	-0.293	-0.247	-0.223	1.000	
GRAD6	-0.231	-0.173	-0.182	-0.131	-0.066	-0.145	-0.247	-0.208	-0.188	-0.184	1.000

TABLE 2. CORRELATION MATRIX OF PUPILS WHO HAVE READING PROBLEMS

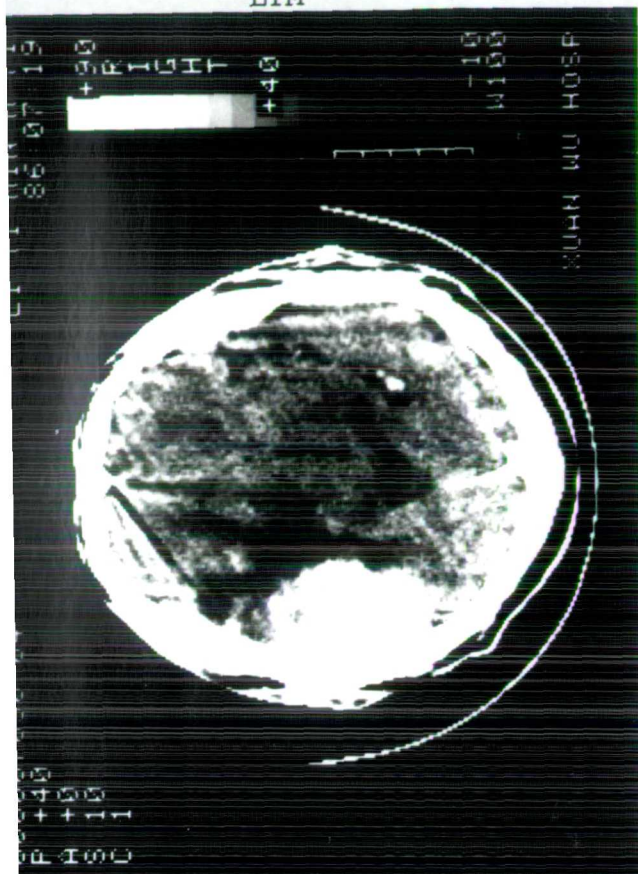
	MALE	FEMALE	LEFTHAND	Q1	Q2	Q3	Q4	Q5	Q6	Q7a	Q7b	Q8
MALE	1.000											
FEMALE	-1.000	1.000										
LEFTHAND	-0.022	0.022	1.000									
Q1	0.57	-0.057	-0.079	1.000								
Q2	0.042	-0.042	-0.087	0.393	1.000							
Q3	0.099	-0.099	-0.099	0.339	0.212	1.000						
Q4	0.012	-0.012	-0.099	0.252	0.174	0.255	1.000					
Q5	0.029	-0.029	-0.057	0.265	0.245	0.232	0.188	1.000				
Q6	-0.005	0.005	-0.060	0.117	0.134	0.152	0.119	0.264	1.000			
Q7a	-0.006	0.006	-0.091	0.253	0.190	0.224	0.195	0.240	0.186	1.000		
Q7b	0.006	-0.006	-0.061	0.226	0.199	0.174	0.160	0.217	0.166	0.263	1.000	
Q8	-0.013	0.013	-0.102	0.240	0.178	0.231	0.170	0.236	0.146	0.338	0.251	1.000
Q9	0.019	-0.019	-0.097	0.260	0.209	0.283	0.229	0.180	0.106	0.208	0.196	0.213
Q10	0.120	-0.120	-0.095	0.125	0.122	0.175	0.141	0.089	0.063	0.064	0.090	0.108
Q11	0.014	-0.014	-0.026	0.106	0.104	0.069	0.135	0.091	0.135	0.049	0.085	0.071
Q12	0.225	-0.225	-0.079	0.022	0.004	0.042	0.070	0.030	-0.002	0.004	0.016	-0.017
Q13	-0.082	0.082	-0.071	0.149	0.083	0.136	0.188	0.084	0.044	0.067	0.083	0.086
Q14	0.022	-0.022	-0.005	0.042	0.060	0.058	0.063	0.009	0.033	0.032	0.061	0.059
GRAD2	-0.054	0.054	0.107	-0.066	-0.017	-0.050	0.015	0.029	0.053	-0.060	-0.081	-0.016
GRAD3	-0.018	0.018	0.006	0.010	-0.001	0.004	-0.008	-0.032	-0.044	-0.076	-0.035	-0.062
GRAD4	0.040	-0.040	-0.027	0.032	0.025	0.037	-0.014	0.019	0.016	0.012	0.066	0.036
GRAD5	-0.004	0.004	-0.058	0.030	0.019	0.066	0.009	0.005	0.016	0.092	0.058	0.046
GRAD6	0.044	-0.044	-0.039	-0.002	-0.028	-0.061	-0.003	-0.024	-0.048	0.045	-0.001	0.001

	Q9	Q10	Q11	Q12	Q13	Q14	GRAD2	GRAD3	GRAD4	GRAD5	GRAD6
MALE											
FEMALE											
LEFTHAND											
Q1											
Q2											
Q3											
Q4											
Q5											
Q6											
Q7a											
Q7b											
Q8											
Q9	1.000										
Q10	0.156	1.000									
Q11	0.120	0.087	1.000								
Q12	0.019	0.225	0.052	1.000							
Q13	0.153	0.030	0.057	-0.060	1.000						
Q14	0.069	0.049	0.038	-0.017	0.045	1.000					
GRAD2	0.061	0.034	0.115	0.009	0.020	0.033	1.000				
GRAD3	0.022	-0.024	0.016	-0.013	-0.013	-0.004	-0.295	1.000			
GRAD4	-0.012	-0.056	-0.009	0.016	0.032	-0.010	-0.276	-0.268	1.000		
GRAD5	-0.011	0.057	-0.084	-0.014	0.002	-0.010	-0.270	-0.262	-0.245	1.000	
GRAD6	-0.072	-0.012	-0.051	0.001	-0.047	-0.012	-0.232	-0.225	-0.211	-0.206	1.000

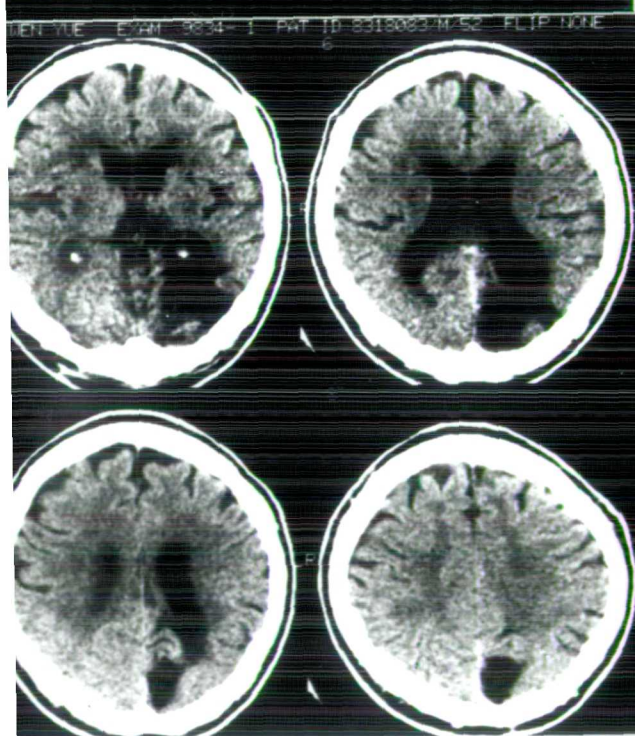
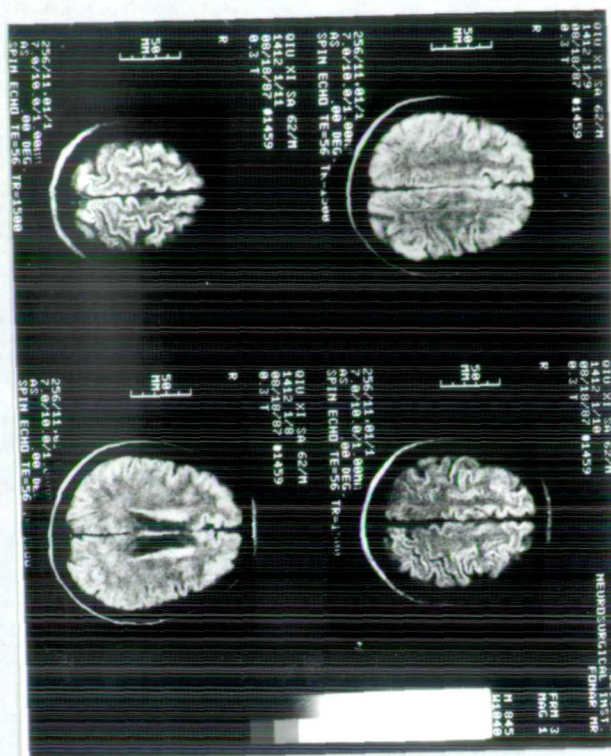
APPENDIX C. CT SCAN OF 11 CHINESE DYSLEXIC PATIENTS



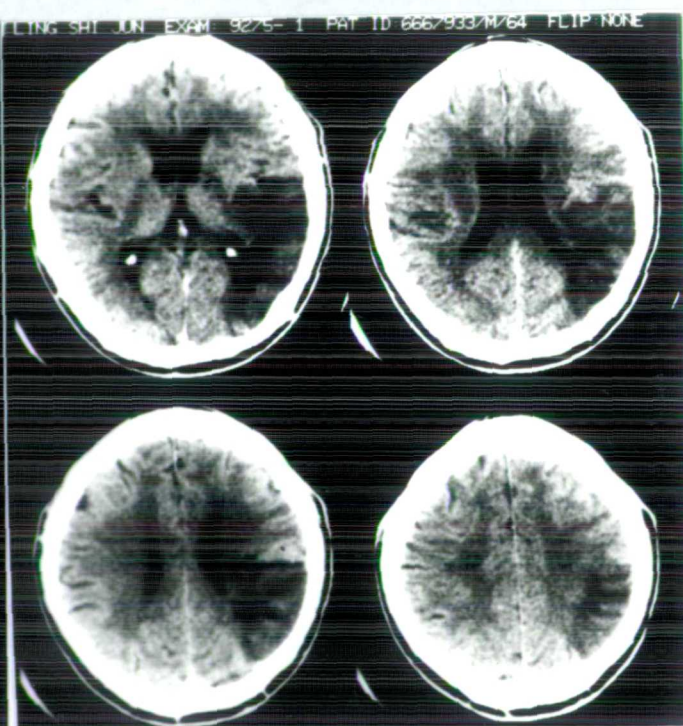
LYM



QXS



LWY



LSJ

SCANNING DARK

WANG BE YING M 55 HEAD FRONT

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H/SP

R I G H T

5 CM

80 32

W C

TI 5
KV 125
AS 45
SL 8
GT -20

UT-685-CT-336163
WITHOUT CM.

[illegible]

ID:32412 BEIJING NEUROSUR NM:LI ZAI-YUI
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